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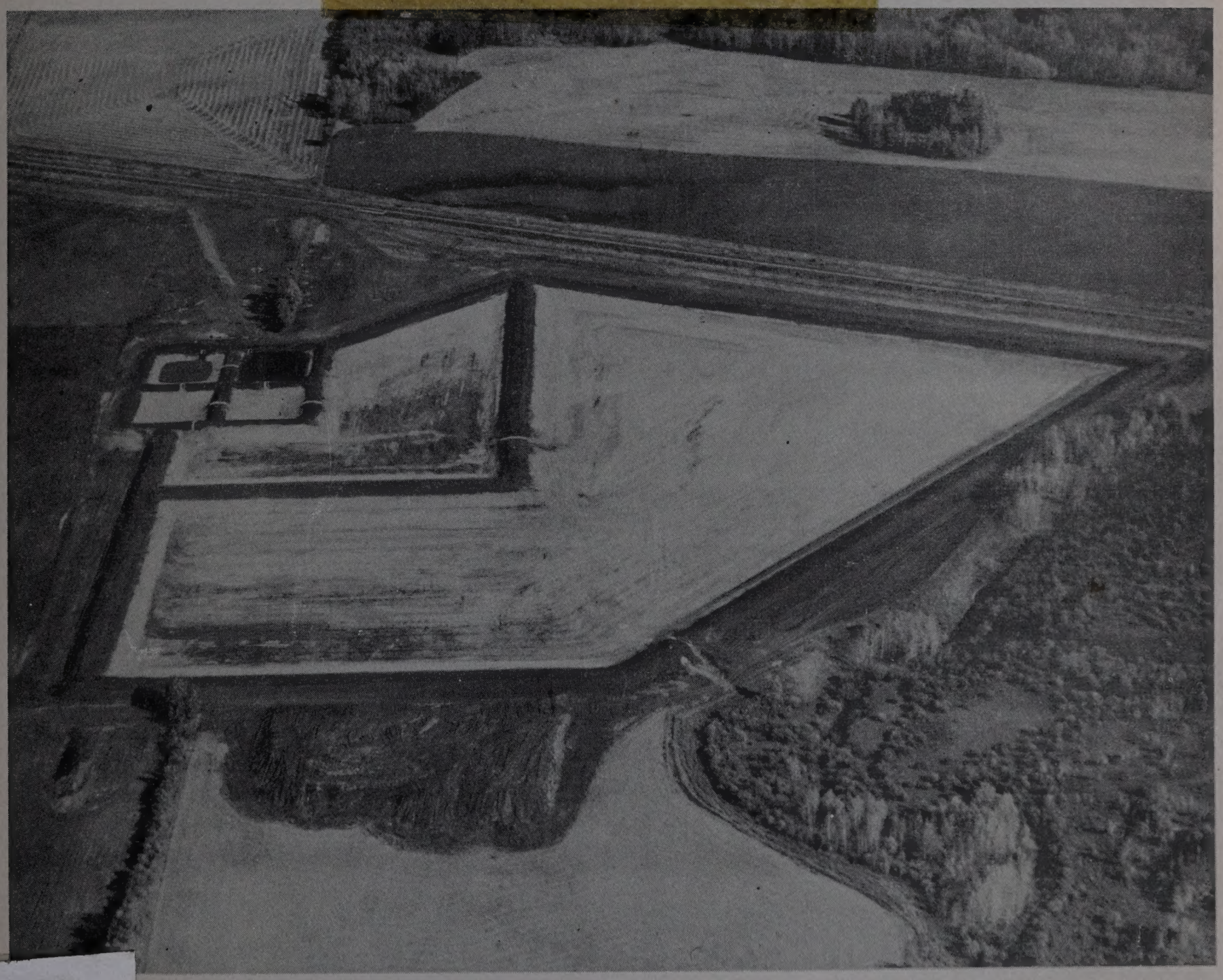
A STUDY OF THE OPERATION OF SEWAGE PONDS IN THE PROVINCE OF ALBERTA



Division of Sanitary Engineering
Department of Public Health
Government of Alberta
Edmonton, Alberta
September, 1961

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A STUDY OF THE OPERATION

OF

SEWAGE PONDS

IN THE

PROVINCE OF ALBERTA

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Edmonton, Alberta

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- Part II: Microbiological Aspects of the Study

Foreword

This study was undertaken by the Alberta Department of Public Health in May, 1958, as a basic study of the nature and the efficiency of the operation of sewage ponds in Alberta. The ponds chosen for study were ones which represented a range of design ideas and loading factors and thus enabled observation of the effect of these factors under both winter and summer weather conditions.

The study was planned to include both the physical-chemical and the microbiological considerations, with both aspects proceeding independently except that samples for both purposes would be collected at the same time and periodic joint discussions of the program and the results would be held. A graduate chemical engineer carried out the physical-chemical section of the work and also collected the samples, made the environmental factor observations and compiled the design and loading data. A graduate student of microbiology, under the direction of the Department of Bacteriology at the University of Alberta carried out the microbiological study. The laboratory facilities of the Department of Bacteriology and the Pollution Control Laboratory of the Division of Sanitary Engineering were used for the laboratory work.

This study was made with the kind permission of the Honourable J. Donovan Ross, M.D., Minister of Public Health and was sponsored financially by the Federal Research Grants program of the Department of National Health and Welfare.

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physical-chemical section of the Department of Public Health under the direction of Dr. D. S. Caverly, M.Sc., Chief Engineer, and Mr. W. L. Mellon, Engineering Assistant. The bacteriological section was under the direction of Dr. J. D. Spinks, Ph.D., Provincial Bacteriologist, and Miss M. Dorothy Porter, M.Sc., Bacteriologist. Mr. R. Hawkes, Technician, carried out the bacteriological work.

The study was made possible by a grant from the Federal Department of National Health and Welfare.

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Summary

The following report records the observations made during this study and the evaluation of these observations.

The initial purposes of this study by the Alberta Department of Public Health were three:

1. To determine the sewage treatment efficiency of the ponds under all seasons of the year.
2. Study the behaviour of the ponds in the spring as related to the release of odorous gases.
3. Consider the advantages of various designs.

The method of study was to consider the physical-chemical factors as one phase and the microbiological factors as a separate phase. The evaluation of the design and loading characteristics of the ponds was included in both phases. Separate reports are included on each phase of the study including all of the data obtained, the observations, methods of sampling & measurement, and the conclusions.

Five ponds were selected for detailed study and these represented both the 'short detention, anaerobic' and the 'long detention, aerobic' ones. They were all within 100 miles of Edmonton so that samples could be collected, returned to Edmonton, and the time-critical tests, such as B.O.D. and Microbiological ones set up in the same day. Spot checks were made on five more ponds, these were of the 'short detention or anaerobic' type. Also ten pond systems in the Peace River district were sampled in June, 1959, in order to observe the operation at a more northerly location, this district being 300

to 400 miles north-westerly of Edmonton. Thus the total number of ponds included in the study was 20, out of a total of about 114 pond systems in operation in Alberta at that time.

The results obtained during this study are summarized in each section of the report, however the following few aspects were particularly interesting:

1. The 'Long Detention Ponds', i.e. those having a detention capacity of at least one month and a B.O.D. loading of not more than 80 lbs. of B.O.D. per acre per day, operate efficiently during the summer months. B.O.D. removal is about 80% and the liquid in the ponds is green colored with algae which supply adequate oxygen to maintain effectively aerobic conditions.

2. Long Detention Ponds constructed as separate units, through which the sewage flows in series, are markedly more efficient than the single unit systems. At the Drayton Valley ponds, the total detention time of the three units is only 120 days as compared to 274 and 204 at Holden and Lacombe; still the B.O.D. removal was 90 to 98% as compared to about 80%, respectively. In addition, the coliform density was as low as 20 per 100 ml. in the final effluent at Drayton Valley, while at Holden and Lacombe the lowest results were about 2,000 per 100 ml.

3. The Long Detention Ponds become anaerobic, i.e. in that dissolved oxygen is not present shortly after the ice cover forms in the winter. One to two months after this the B.O.D. of the liquid in the ponds starts to increase as does the Threshold

Odor Number, the alkalinity, total solids, ammonia and chlorides; at the same time the pH and suspended solids decrease. This is partly due to the concentrating effect of the ice formation, however the B.O.D., ammonia and alkalinity increased to a greater extent than did the total solids and chlorides, thus indicating changed microbiological activity and decreased treatment efficiency. The graphs of the results of the Holden and Lacombe systems, on pages 44-45 and 55-56 of Part I indicate this, as does the following table:

	Value at the Time of Ice Formation		Approx. Peak Value During the Winter		% Increase During this Period	
	Lacombe	Holden	Lacombe	Holden	Lacombe	Holden
Total Solids, ppm.	1130	3560	1580	5000	40	40
Chlorides, "	70	390	105	600	50	54
B. O. D. "	40	85	280	290	600	240
Ammonia-N "	15	10	75	90	400	800
Alkalinity "	570	800	1300	2400	140	200

4. The differentiation between aerobic and anaerobic conditions appears to be a technically debatable matter in that the number of bacteria cultured in the laboratory under aerobic conditions remains at a high level throughout the winter and also algae were present in large numbers in the winter samples. The numbers of coliforms and of bacteria cultured under anaerobic conditions in the laboratory appear to follow a seasonal cycle in the Long Detention Ponds, reaching a maximum in the late

winter and early spring and then declining to a lower level during the summer. This would indicate that both aerobic and anaerobic decomposition processes are active throughout the year, although the anaerobic ones are appreciably less significant during the summer season.

5. The survey of the ten ponds in the Peace River district shows that the summer time operation is very similar to that in the Edmonton area. It is noted that at Donnelly and Girouxville the dissolved oxygen was very low, no algae were observed in the samples and the B.O.D.'s were also low.

6. The highest degree of treatment observed was at Drayton Valley. The three 'long detention ponds' in series here were sampled over a 24 hour period in September 1959, with the following results:

	Raw Sewage	Final Effluent	% Removal
B.O.D.	302	6	98
Ammonia	21	1.8	91
Phosphate	34	4	88
Detergents*	18 (Est.)	6	67.7
Suspended Solids	532	48	91

*Commercial Detergent, determined by analysis for ABS.

Other observations in the third pond of the system also indicated a high degree of purification, e.g.

a. The algae were too few for an accurate count;

b. Coliforms were 20 and 680 per 100 ml., top and bottom samples respectively;

c. Anaerobic bacteria were 3 and 4 per ml., top and bottom respectively;

d. Dissolved oxygen ranged from 1.4 to 7.3 p.p.m. during the day of sampling;

e. The pH was 8.55.

7. The three 'short detention ponds' operated in series at Stony Plain gave quite consistent B.O.D. removals of about 70% during both winter and summer seasons. The removal of ammonia and phosphates seems to be quite low. Microbiological results indicated fairly uniform concentrations of bacteria and algae through the year. The limited tests on the storage pond which receives the effluent from these ponds indicated that a high degree of treatment is accomplished by combining the 'short' and 'long' detention ponds. See Table IX on page 72, Part I.

8. Checks were made of five other 'short detention' pond systems by collecting single composite samples of raw sewage and pond effluent on four of them, and a total of ten samples on the other one. These had detention times ranging from 1.9 to 10.4 days and the indicated B.O.D. removals ranged from 15.7 to 54.3%. Appreciable odors were noted at two of these systems, however in one the sulfate content was high, varying between 650 and 1100 p.p.m., and at the other one a cheese factory was served by the sewerage system. The optimum detention time appeared to be about five days on the basis of B.O.D. reduction in this survey.

9. It is interesting to note that the numbers of 'aerobic' bacteria

and algae remain at fairly high levels until the sewage is very highly stabilized, e.g., Drayton Valley and Stony Plain systems. The 'anaerobic' bacteria and coliforms decrease in the 'long detention' ponds in the summer, but are at a high level during the winter and early spring. There is no appreciable change in these microbiological considerations in the 'short detention' ponds throughout the year. The most sensitive indicator of pond operation in the chemical analysis is the B.O.D.s, but the ammonia, phosphates, alkalinity and pH changes are also indicative of the changes in the degree of the sewage treatment being accomplished. The chlorides are a good indicator of the concentrating effect of this ice as is the total solids determinations.

10. The observations obtained in this study indicate that the 'short detention' ponds are efficient in reducing the B.O.D. of sewage during both the winter and summer seasons. A high concentration of sulfates and some industrial wastes may cause some odor problems with these, however for the treatment of normal sewage, odors were not significant. This feature is important for the winter operations of the pond systems, particularly if ice cover is present for more than about one or two months. It is also suggested that the B.O.D. reduction preceding the 'Long Detention Ponds' will reduce the odors emanating from these ponds in the spring, both in intensity and time of duration.

11. In view of the findings of this study the Department of Public Health is requesting that the basic design of pond systems

in Alberta, provide four 'Short Detention Ponds', each having a detention time of four days at the current sewage flow rate; and two 'Long Detention Ponds', each having a detention time of at least one month and a combined detention time of six to twelve months depending on local circumstances.

Also, consideration is now given to the use of 'Short Detention Ponds' where a B.O.D. removal of 50 to 70% is adequate to avoid adverse pollution of the river receiving the treated sewage. This study has been useful in assisting municipalities to release the stored sewage from the ponds at the most opportune time of the year. As the quality of the liquid in the ponds is at its poorest level during the latter part of the winter and early spring, and at its best level during the summer and early fall, maximum benefit of the treatment available is obtained by allowing the ponds to overflow continuously during the summer-early fall seasons, and draining them down in the fall so that no overflow is necessary during the winter and early spring seasons. In some cases, it is possible to gradually drain down the ponds during summer and operate at a liquid level of about one foot throughout the fall and early winter seasons, then storing the sewage again over the winter-spring seasons.

The general nature of this study has prevented detailed analysis of certain operating factors and of critical loading parameters. It is planned to continue the study in order to evaluate the revised design practise and to

carry out more detailed analysis, particularly of the actual loading applied to the ponds, the series operation of the ponds, and the B.O.D. reductions in the short detention ponds.

It is hoped that the distribution of the results of this study will contribute to the understanding of the operation of sewage ponds.

H. L. Hogge, Director,

Division of Sanitary Engineering.

A STUDY OF SEWAGE PONDS IN ALBERTA

PART I

PHYSICAL-CHEMICAL ASPECTS

together with the

DESIGN and LOADING FACTORS

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together with the

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SEWAGE STABILIZATION PONDS IN ALBERTA

INTRODUCTION

In recent years sewage stabilization ponds have been used almost exclusively as a means of sewage treatment in the smaller communities of Alberta. This popularity is due to a number of factors which are as follows:

1. Low initial costs
2. Low operating costs
3. A high degree of treatment
4. Minimum of nuisance or offensive odor, and
5. Ease of operation

Ponds in Alberta also provide storage for the sewage flows which otherwise would have to be chlorinated in order to permit discharge into a drainage course without creating a health hazard. Sinze this is an agricultural province, the storage prevents the flooding of farm land and the ensuing nuisance which eventually would bring complaints from farmers.

Out of the 187 communities served by sewerage systems, 114 of them operate some type of ponding for their sewage treatment. Because of common use of ponding, the Division of Sanitary Engineering, Department of Public Health, set up a research program to investigate the principle factors affecting the operation of the ponds, and also to evaluate the operating efficiencies of the various types of ponding systems in use in Alberta.

TYPES OF STABILIZATION PONDS USED

At present there are 5 different types of pond systems used in Alberta:

1. Long detention, single cell
2. Short detention, single cell
3. Multicell, all long detention cells

4. Multicell, all short detention cells

5. Combination of short and long detention cells

The choice of the system usually is governed by the location of the town; that is, whether it is by a good drainage course, a large flowing stream, or near a large slough. Each system is discussed briefly herein.

1. Long Detention, Single Cell

This is the predominant type of pond used in Alberta. They are known as aerobic ponds with holding periods of six months to one year or more. Long period ponding is used for towns near which there is no dilution available for sewage effluents, and in many cases where no well defined water course is available. The ponding periods are so chosen that the ponds can be drained twice a year (usually in the spring and fall), or once a year without harming adjacent farm lands.

A variety of ways for construction of the ponds have been used with the majority being built as rectangular or square diked structures on flat land. Another good portion have been built following natural contours or depressions and still others have used existing sloughs.

Treatment by the long period ponding has been found to be very good in the summers with B.O.D. or organic material removal of 80 to 90% (Lacombe), while late winter (February and March) operation may get a removal as low as 30 to 40% (Lacombe & Holden).

The poor winter operation is mainly affected by ice cover which might be equal to, or greater than the thickness of the liquid layer portion. Associated with the ice cover, and which also contribute to the poor winter operations are low temperature and poor liquid circulation in the pond. With the formation of ice approximately two feet thick and a snow cover, insufficient light penetrates

into the liquid in order that treatment is continued to the fullest with the help of oxygen producing algae.

2. Short Detention, Single Cell

Short period ponding has been used as being equivalent primary treatment (screening and settling) where a constant discharge from the pond is feasible, as for example in the case of the pond discharging into a running stream or fairly large lake. The ponds produce an effluent very low in settleable solids and with a much lower B.O.D. than the effluent from primary settling tanks.

These ponds are known as anaerobic ponds and their use has increased lately because of favourable results obtained on their operation. These ponds removed a high percentage B.O.D. and suspended solids per unit area. Depths of greater than five feet are common as sunlight does not increase efficiencies. The data shows that under ice and snow covers, the same B.O.D. removals were obtained as in the summer, open water periods (Stony Plain & Daysland).

Very good B.O.D. removals by short period ponding were obtained (see table below) in all cases where depth of 4 feet to 8 feet were used. Two Hills, where depths of 18 feet and 10 feet are present for ponds #1 and 2 respectively showed lower removals for approximately the same detention time as other ponds. The 18 foot deep pond with a removal of 15.65 is low when compared to the others with removals of 30 to 45% with detention periods of 1 to 12 days.

Depths up to 10 feet and detention periods up to 10 days are recommended for best design and efficiency of these short detention ponds. One of the first to be installed in Alberta (Warner) was designed soley to replace the septic tank. This type of arrangement has been used in Australia * with success.

* Sewage and Industrial Wastes 22,760-75 June, 1950
Sewage and Industrial Wastes 31,133-52 February, 1959
Public Health Engineering Abstracts - August, 1950, Vol. XXX No. 8
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TABLE I

Table of Short Detention Ponds & Performance

Town	Detention Time, Days	Depth, Ft.	B.O.D. Removal %
Calmar	4.65	4	54.3
	60.2	7	38.8 (winter)
*Daysland	6.2	6	47.8
Myrnam	11.7	6	30.5
	24.2	4	8.0
*Stony Plain	0.93	5	33.4
	0.93	5	32.2
	2.6	5	30.7
Thorsby	10.35	8	42.2
Two Hills	1.9	18	15.7
	1.05	10	21.4

* Indicates regular sampling points while all others are spot checks.

3. Multicell, All Long Detention

This type of system, two or more ponds in series, is present in Alberta in a minority, with only 5 towns operating such a system. One of these, at Drayton Valley, was observed and studied throughout the year and another at Fairview, had only a spot check done on it in the summer of 1959.

The Drayton Valley system consisting of 3 ponds in series, operated very efficiently in the summer with a B.O.D. removal of 91.2% and the winter operation was somewhat lower with a removal of only 64.5%. A continuous overflow is permitted in the summer and a draw down in the fall makes it possible to store the winter flow.

The rapid expansion of the Town of Drayton Valley necessitated further sewage treatment, thus additions were made to the pond giving the present system.

The lone Fairview sample had a low B.O.D. of 40 ppm , thus showing a very good treatment. Unlike Drayton Valley, Fairview had no suitable drainage course making it necessary to store the sewage flow and release it at suitable times of the year.

4. Multicell, All Short Detention

A system of this type is not too common in Alberta. Up until the summer of 1959 Stony Plain operated one of these systems which consisted of three ponds in series. They operated very efficiently throughout the summer and winter with a total removal of approximately 70% with each pond as a single unit removing approximately 30%. At no time were there any odors present at distances of 100 feet away.

Two Hills operates a system of this type, but only two ponds in series are present with depths of 18 and 10 feet for ponds #1 and 2 respectively. A spot check of the system showed that the first pond had a low efficiency of 15.7% for 1.05 days detention period and the second pond was somewhat better with an efficiency of 21.4% for 1.9 days detention. It is quite possible that only the top 5 feet or so does the effective treatment because of the top side inlet present.

5. Combination of Short and Long Detention Ponds

In number of installations this system of ponding is next after the single cell, long detention ponds. Recent work shows favourable results obtained on the combination and recommendation for the use of these in present and future installations are being made.

There are two main reasons for using this combination; firstly, three short detention ponds in series under anaerobic conditions will give a B.O.D. removal of up to 70% (Stony Plain) and secondly, a six month or one year detention pond will give additional treatment plus storage. This further treatment gives an effluent equivalent to tertiary treatment in the summer (Stony Plain with a removal of 98%) and in the winter an equivalent to secondary treatment.

SAMPLING OF THE POND AND RAW SEWAGE

The sampler, as described in Standard Methods, 10th Edition, on pages 250 and 251, was used for the ponds. The samples, where convenient, were collected at the effluent of the ponds and also from constructed rafts (Holden & Lacombe) in the summer. Winter sampling was done mostly through the ice with the sampler.

At the time of sampling, dissolved oxygen, time, temperature, weather and pH were recorded and also any other oddities which were not too numerous.

Composite raw sewage samples were collected manually at intervals of two hours from 7:00 a.m. to 11:00 p.m. inclusive. The samples were collected at manholes close to ponds or at lift stations if one was present. Sample sizes were judged by the depth of flow in the outfall sewer for gravity flows, and where lift stations were used by the length of time to fill the wet well for pumping.

As most of the towns where sampling was done are within a one hundred mile radius of Edmonton, there was no excessive delay in the analysis of any of the samples.

MEASUREMENTS OF SEWAGE FLOWS

The following four methods of sewage flow measurements were used:

1. Recording ammeter
2. Mannual timing of pumping and fill up time for the wet well
3. Salt dilution
4. 90° V-Notch weir

In obtaining a total flow for a 24 hour period, the first two methods are quite accurate while the last two methods may be questionable because they are only spot checks of the flow. A metering device for the weir would increase the

accuracy to that of the first two methods.

The first two methods can be used only where a lift station is operated, while the last two can be used only where gravity flow is employed.

1. Recording Ammeter

This device is operated by simply placing a special clamp around a single insulated power inlet wire to the motor of the pump. Each time the motor starts, the current in the wire induces the clamp so that it records the amperage and the running time on the recorder and when it stops, the current drops to zero. By simply measuring the time of each operation, a very accurate flow rate is obtained for any length of time the recorder is left in operation.

2. Manual Timing

This method is simply recording the time it takes to fill up the wet well of the lift station and also recording the pumping time. With this information, a very accurate flow rate can be obtained.

3. Salt Dilution

For this method, an approximate flow rate was calculated of the town so that an estimate of the required sodium chloride solution, which, when diluted down by the flow, would give a difference of 100 ppm. of chloride.

This measurement was carried out between two manholes. At the first manhole, a definite, constant head, flow rate of the salt solution was dripped into the flowing sewage. At the second manhole, an initial chloride sample was collected and subsequent samples at intervals of one minute were collected until such a time that the chloride content was constant. A measurement of the salt solution at the start and end of the run gave an average flow over this period of time. A simple material balance gives you the flow rate at this particular time.

A number of these were run throughout the day and it made it possible

to obtain to some degree of accuracy the total flow for the day.

4. Weir Measurements

A weir which was specially constructed to fit into a manhole was used in measuring the flow. Levelling devices on the weir were used so that accurate measurements could be made at specified distances for weirs.

An equation was used to calculate the flow and with a number of measurements it made it possible to obtain some degree of accuracy for the total flow in the day.

This method if simpler to operate than the salt dilution and with the addition of a metering device, the accuracy would be just as great as the first two methods.

GENERAL LOADINGS AND FLOWS

TABLE II

Town	Population Served	B.O.D. ppm.	B.O.D. lbs/cap/day	Suspended Solids ppm.	Suspended Solids lbs/c/day	Sewage Flow g.p.c.d.	Water Consumption g.p.c.d.
Bruderheim	220	394	0.358	360	0.327	91.0	-
Drayton V.	2800	302	0.261	532	0.462	86.3	76.8
Holden	450	485	0.308	477	0.302	63.4	44.5
Lacombe	2835	338	0.132	204	0.080	39.1	40.2
Myrnam	420	236	0.0645	193	0.053	27.4	19.1
Stony Plain	1040	335	0.245	329	0.240	73.0	68.6
Two Hills	800	294	0.195	214	0.142	66.2	33.5
Average		341	0.223	330	0.229	63.8	47.1

Indicated on Table II are the averages for B.O.D. suspended solids, sewage flows and water consumption figures for seven towns in Alberta. These are indicative of the range of values which may be encountered, and the average values for design purposes, if specific information is not available.

SUGGESTED OPERATING CONSIDERATIONS

There are a number of general operating and maintenance considerations required in operating a ponding system. Upon completion of the construction, any uneven ground on or near the berms should be levelled and the berms sown into grass to the water line. Use a grass of a type that will prevent erosion of the soil used for construction. The grass should be mowed periodically and the weeds sprayed.

A stock-tight fence should be built and kept in good repair around the ponds. This will prevent larger farm animals from tramping down the berms and causing a possible overflow at a weakened point. Appropriate signs should be provided to designate the nature of the facility.

Inspect the berms periodically and repair them immediately when needed in order that greater problems are not created. Burrowing animals should be controlled, since they may weaken the berm structure and may possibly plug overflow lines.

The bottom of the ponds should be level which will prevent mounds of dirt covered with sludge from showing and releasing odors when the pond is drained. Destroy all vegetation growth in the ponds to prevent insect propogation such as mosquitoes.

TYPICAL DESIGN CONSIDERATIONS FOR SHORT AND LONG DETENTION PONDS

TABLE III

Structure	Short Detention	Long Detention
Number of ponds in series	4	over 3 acres - 2 ponds
Capacity, detention time	4 days	6 months or 1 year
Depth, feet	5 - 10	3 - 5
Freeboard, feet	2	2
Berms: Width at top, feet	5	10
Slopes (minimum) Vertical to Horizontal		
Inside, Submerged		
Clean sand or gravel	1:2	1:2
Clean clay	1:15	1:15
Mixtures	1:3	1:3
Inside & Outside, Non-submerged		
Clean sand	1:1.5	1:1.5
Clean gravel	1:1.33	1:1.33
Clean clay	1:1.75	1:1.75
Mixtures	1:1.5	1:1.5
Inlet Sewer	2/3 of depth down and end of outfall 2' or 3' into pond.	Along bottom of pond, but not necessarily to center if short detention ponds present.
Overflow	Either a line from top to depths as above or through a baffled-gravel or rock lined ditch or concrete flume.	Final effluent from near bottom and into drainage course with level control and also an overflow structure provided.

Berm structure will be solely governed by the presence of the type of soil in the area. If the native soil is porous and there is a danger of pollution of the underground waters or other damage by seepage, the entire ponds should be made water tight. The berms should be sown in grass down to the water line and maintained as previously described.

The ponding system should be located, if possible, so that any odors are not carried to the community or other residences by prevailing winds. They should be a minimum of one-half mile from the community boundary, one-quarter mile from any other residences and no less than 100 and preferably 300 feet from any road or railroad. This reasonable isolation is necessary as ice coverage results in anaerobic conditions in long detention ponds during the winter and some odor potential is present during the transition period from ice cover to open water. Also the short detention ponds are anaerobic throughout the year and give off some odor. All surface drainage from adjacent areas should be excluded and proximity of ponds to water supplies and known water aquifers should be critically evaluated in accordance with sound sanitary practices.

CONCLUSIONS AND GENERAL PLAN

In concluding the research project, it was found that a general design could be recommended from the observations and results obtained.

The operation of short detention ponds in this part of the country where ice cover is present from November to April was found to be very favourable throughout the year. This is due to the fact that the short detention ponds operate under anaerobic conditions throughout the summer and no changeover occurs when an ice cover is obtained, as is the case for aerobic or long detention ponds.

It was also found that a high B.O.D. and suspended solids removals were obtained per unit area providing that the sludge from the pond was removed periodically when necessary. If the sewage flow was allowed to channel through the sludge filled pond, it would be defeating the purpose for which the pond operates and would also fill up subsequent short detention ponds as the channelling would

carry over suspended solids in the raw sewage.

Depths for the short detention ponds of five to ten feet are recommended unless the influent line is some distance below the surface of the pond in which case depths of greater than ten feet could be used.

The ponding system which is recommended is a combination of short and long detention ponds in series. The anaerobic section would consist of a minimum of three, 3 to 5 day detention ponds in series, while the aerobic section would consist of two 3-month or two 6-month detention ponds depending on the location of the town. The purposes of the aerobic section would be; firstly, for storage and secondly for further treatment. If a proper drainage course is absent, detention time of one year is required and then drawn down at the convenience of the town and surrounding farmers who might be inconvenienced. Six months detention should be installed where a well defined drainage course is present, thus, allowing two draw downs a year usually in the spring and fall, or one drawdown in the fall and a continuous overflow during the summer.

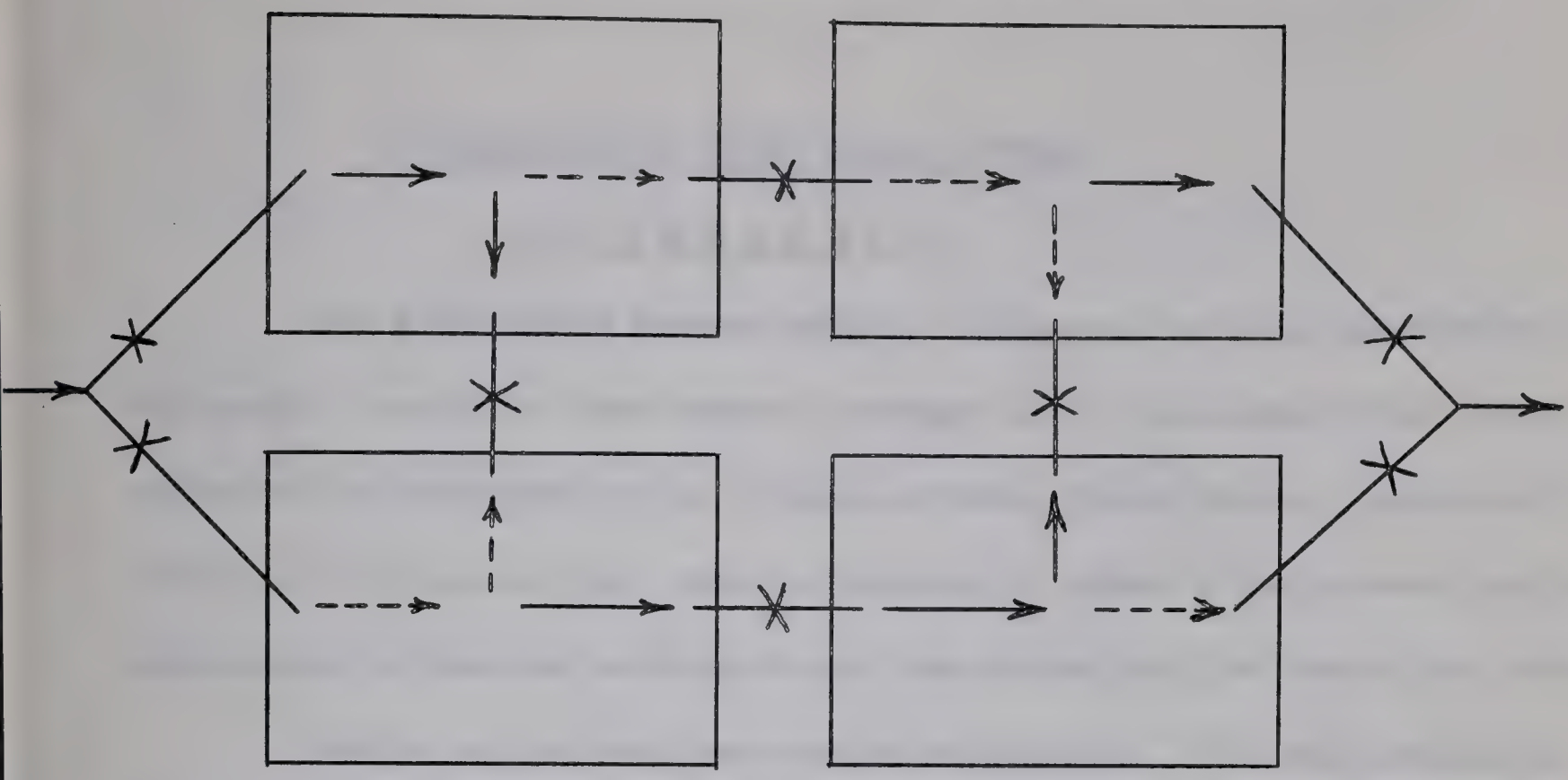
A single long detention pond will be permitted up to three acres. Beyond this size the pond should be broken into two equal sized sections up to a reasonable limit of size.

The anaerobic ponds should be built in an isolated area (as previously described) and should have stable submerged slopes. The isolation will prevent an odor nuisance which generates in small amounts from the anaerobic ponds. The overflow should have some type of skimmer to prevent the passage of floating material from one pond to the next.

A fourth short detention pond could be used so that it could be alternated with another into which raw sewage would flow. This would allow the sludge to digest thoroughly before being removed. The sludge could be disposed of by either placing by the pond and allowing it to dry completely and then spreading it on a field or it can be spread wet on the fields.

It is believed that by this complete method of sewage treatment, pollution and health hazards will be kept to a minimum and flooding of farmland will be prevented.

SCHEMATIC LAYOUT OF SHORT DETENTION PONDS



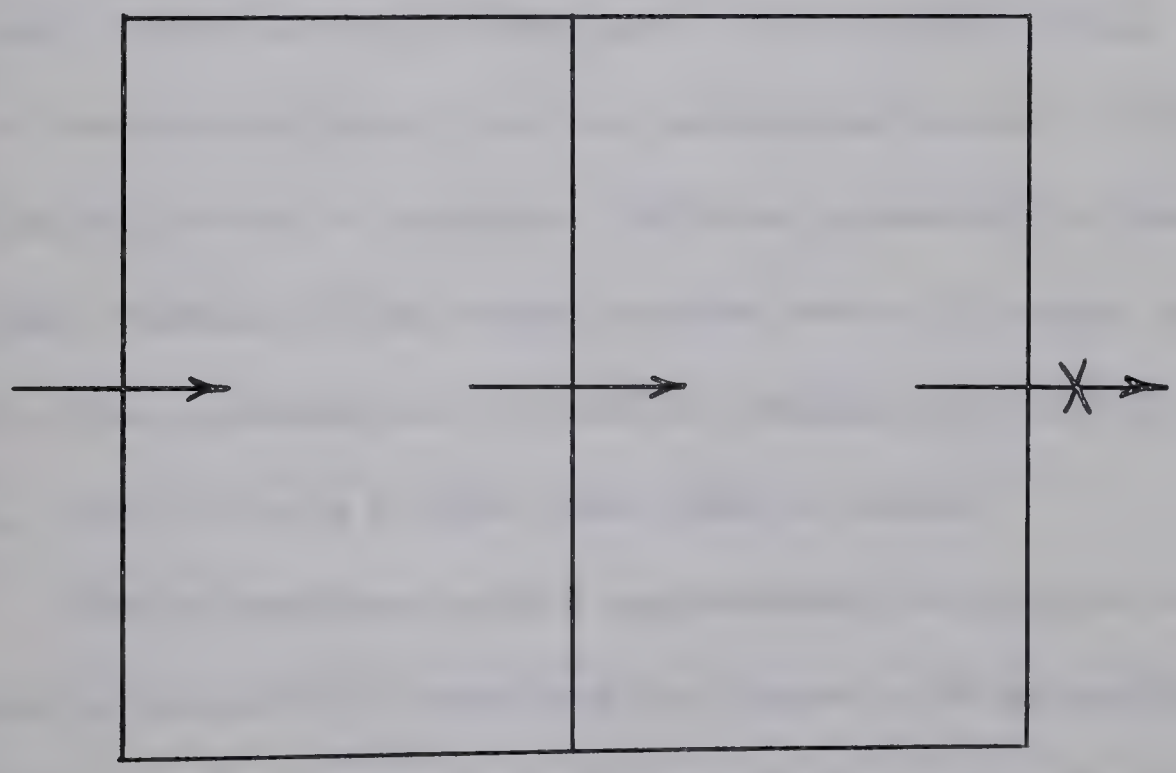
→ Flow route during 1st year.

- - - ➤ Flow route during 2nd year.

Detention Time: 4 days

B.O.D. Loading: 600 to 5000 lbs./acre/day.

SCHEMATIC LAYOUT OF LONG DETENTION PONDS



Detention Time: 3 or 6 months in each section.

B.O.D. Loading: not to exceed 60 lbs./acre/day.

Figure I

OPERATION OF INDIVIDUAL PONDS

BRUDERHEIM

The Bruderheim sewage pond of 3.67 acres, serving a population of 220 people, receives a raw domestic sewage from a community which uses individual private water wells. It also serves a cheese factory, producing 855 lbs. of cheese per day. Most of the whey is taken by the farmers and the main waste is from the washing of vats (the cheese) and the floor of the factory.

Studies on this pond were begun on May 21st, 1958 and terminated on January 5th, 1960. A composite raw sewage sample was collected during a 24 hour period on August 26th and 27th, 1959, and during this period, measurements of the flow were made by the salt dilution method.

The B.O.D.'s of the pond were found to be high for the summers of 1958 and 1959 with an average of 465 ppm and the ice cover B.O.D.'s were also high, with an average of 888 ppm. The summer B.O.D. average of 465 ppm is considerably higher than the raw sewage B.O.D. of 394 ppm obtained on the particular day of sampling. With the presence of a cheese factory which puts washings of the cheese into the sewer, it is quite possible that a sample of the washings was missed as sampling was carried out every two hours, thus, giving a B.O.D. lower than the actual.

Cheese washings contain approximately 20 per cent of the whey because it cannot be completely drawn from the cheese in the processing. This information and the average B.O.D. contribution per capita can be used in calculating a possible raw sewage B.O.D. rather than considering the 394 ppm value obtained. The following is an example of a possible raw sewage B.O.D. for a flow of 20,000 gallons per day.

Contributions per day by the town:

Average B.O.D. contribution - - -	0.223 lbs./capita/day	
B.O.D. contribution by 220 people - -	49.0 lbs./day	
Total whey - 90% total milk - -	7700 lbs.day	
20% whey in washings - -	1540 lbs./day	
B.O.D. of whey - -	51,750 ppm	
B.O.D. contribution by whey	79.7 lbs./day	
Total contribution		128.7 lbs./day
B.O.D. for 20,000 gal./day		644 ppm

The calculated B.O.D. would give a summer removal of 26.4% which is quite low and the winter average of 888 ppm is still above the calculated B.O.D. of 632 ppm. It is possible that in the winter the total whey coupled with the freezing would bring the B.O.D. of the pond to a very high value.

A strong odor had been present near the pond throughout the summers of 1958 and 1959 and at the same time the total and ammonia nitrogens remained at a high concentration. Samples from beneath the ice gave high odors of sour milk or creamery wastes, and also high B.O.D.'s with a maximum of 2160 ppm on March 10th, 1959. Increases were also recorded in alkalinities, phosphates, chlorides and total solids while the pH dropped below 7.0 which is the only case observed during the study for any of the long detention ponds.

Jar tests, carried out in the summer of 1958, using sodium nitrate, ammonium nitrate and phosphates did not indicate definite improvements in odor levels. Assuming that a full pond with a continuous overflow for the summer of 1959 would improve conditions, it was not drawn down in the spring of 1959, but once again the odors were quite appreciable.

The pond is regularly operated with two draw downs per year, one in the spring and one in the fall.

Analysis in ppm of the composite sample of water from three individual wells in the Village of Bruderheim:

Total Solids	650
Ignition Loss	132
Hardness	270
Sulphates	104
Chlorides	24
Alkalinity	405
Nature of Alkalinity	Bicarbonate of soda, lime and magnesium
Nitrites	Trace
Nitrates	3.9
Iron	0.8

BRUDERHEIM

POPULATION - 315 Serving Approximately - 220

Water Consumption - Individual water supplies
Sewage Flow - 20,000 gals./day
Number of Connections - 57

SIZE OF POND:

Dimensions - 400' by 400'
Area - 3.67 acres
Capacity @ 4 ft. depth - 4.0 million gals.
Detention Time - 200 days

LOADING:

21.5 lbs. B.O.D./acre/day
B.O.D. Contribution per Capita - 0.358 lbs./day
Sewage Flow per Capita - 91 gals./day

SKETCH OF BRUDERHEIM SEWAGE POND

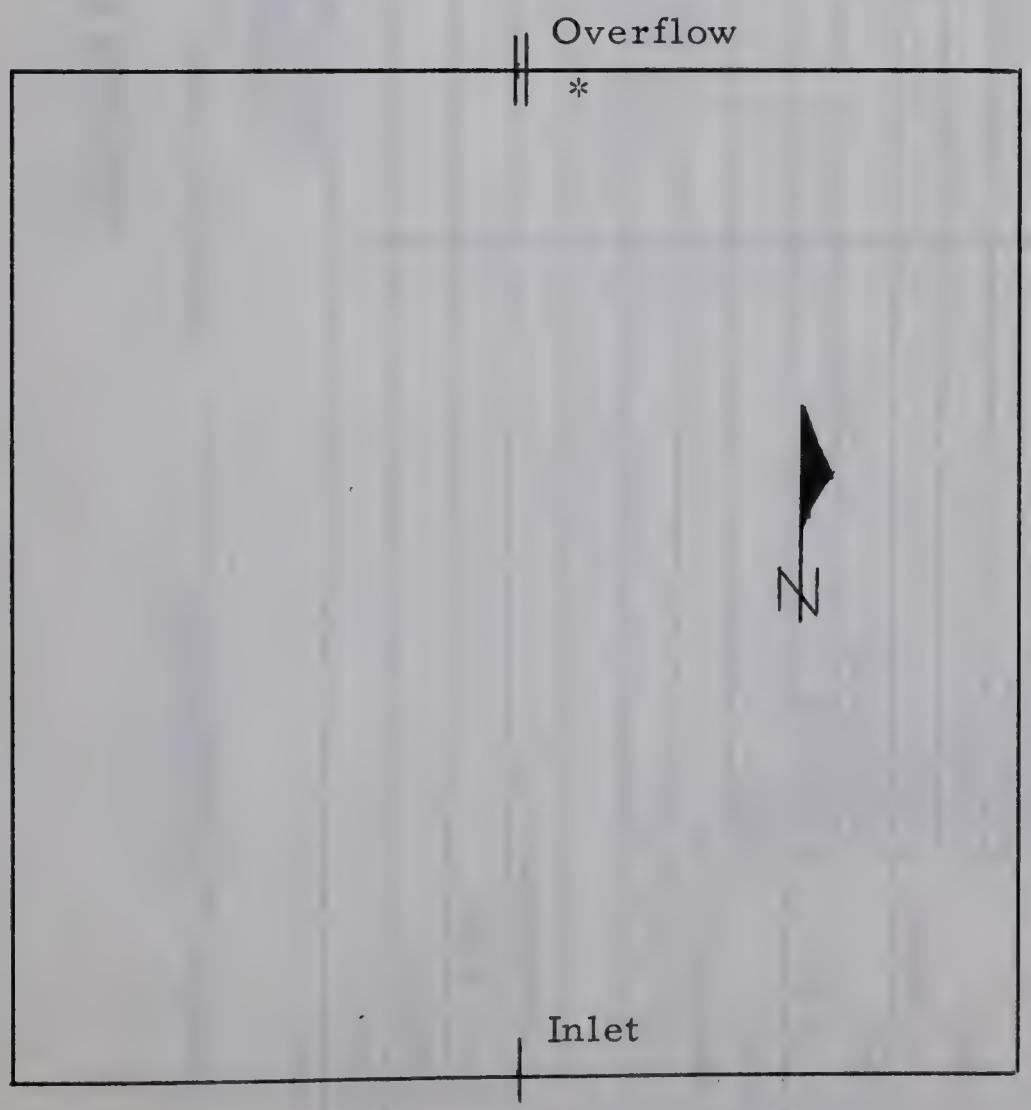


Figure II

Scale: 1" - 100'

* Indicates Sample Point

Table IV

SEWAGE POND RESEARCH PROJECT

Location: BRUDERHEIM Sampling Point:

Date		Composite Ice Sample March 10, 1959	Composite Raw Sewage August 26 & 27, 1959
Time			
Weather			
D.O. ppm			
Temperature, °C			
pH		7.2	7.35
Odor, T.O.N.		500 Cr. Waste	500 sewage
Alkalinity, ppm	pp	0	0
	MO	108	635
B.O.D. ppm	Filtered		
	Unfiltered	121	394
Nitrogens ppm	Total	8.7	28.0
	Organic		4.8
	Ammonia	6.3	12.5
	Nitrite		0.98
	Nitrate		1.22
Total Solids, ppm	Total	451	1545
	Volatile	282	601
	Fixed	169	944
Suspended Solids, ppm	Total	160	360
	Volatile	132	174
	Fixed	28	186
Chlorides, ppm		16	80
Sulfates, ppm		26.3	145
Phosphates ppm		10.2	17
Others			

Table IV

SEWAGE POND RESEARCH PROJECT

Location: BRUDERHEIM Sampling Point: At the outfall on the north side

Date		1958 May 21	May 28	June 4	June 11	July 3	July 3	July 30	Sept. 30	Nov. 27
Time										11:00 a.m.
Weather										Fine & Cold
D.O. ppm		0	0	0	0	0		0		0
Temperature °C		18								0.25
ph		7.5	7.8	7.2	7.1	7.6		7.75	7.8	7.7
Odor, T.O.N.		1600 Cr. Waste	800 Cr. Waste	1600 Cr. Waste	800 Cr. Waste			500		4000 Sewage
Alkalinity, ppm	pp	0	0	0	0	0		0	0	0
	MO	471	516	501	531	750		810	825	895
B.O.D.	Filtered					339	Centri-	169	184	103
ppm	Unfiltered	>432	638	825	697	382	fuged 375	364	314	259
Nitrogens	Total								23.2	32.9
ppm	Organic									
	Ammonia								12.7	22.1
	Nitrite									
	Nitrate									
Total	Total				1923	2135		2272	1572	1706
Solids,	Volatile				1059	1139		1216	614	641
ppm	Fixed				864	996		1056	958	1065
Suspended	Total	280	500	480	456	816		190	336	324
Solids,	Volatile	258	416	364	364	688		100	296	248
ppm	Fixed	22	84	116	92	128		90	40	76
Chlorides, ppm									152	160
Sulphates, ppm										105
Phosphates, ppm										
Others Turbidity ppm SiO_2		345	410	370	620					

SEWAGE POND RESEARCH PROJECT

Location: BRUDERHEIM Sampling Point:

Date		1959 Jan. 8	Feb. 4	March 10	June 10	July 29	Aug. 26 & 27	Oct. 14	Dec. 2	1960 Jan. 5
Time			3:30 p.m.	3:30 p.m.	1:30 p.m.	2:00p.m.	24 hour composite	3:00 p.m.	2:30 a.m.	11:45 a.m.
Weather			Sunny & cold	Sunny & Warm	Rainy & Cool	Sunny, Windy & Warm	Overcast & Rainy	Fine & Warm	Over-cast & Cool	Over-cast & snowing
D.O. ppm		0	0	0	0	0	0	0	0	0
Temperature °C			1		14	20		11	0.75	1
pH		6.7	6.4	5.95	7.3	7.3	7.75	7.6	7.0	6.95
Odor, T.O.N.		10,000 Cr. Waste	15,000 Cr. Waste	20,000 Cr. Waste	4,000 Cr. Waste	1,000 Cr. Waste	2,000 Cr. Waste	100 Cr. Waste	2,000 Cr. Waste	
Alkalinity, ppm	pp	0	0	0	0	0	0	0	0	0
	MO	2150	3255	1390	838	890	855	825	1150	1190
B.O.D. ppm	Filtered				465	240	134	109		
	Unfiltered	645	>1630	2160	683	340	203	236	324	310
Nitrogens ppm	Total	85.4	138	77.8	39.8	28.3	33.0	29.3	36.7	
	Organic				14.8	6.2		5.3	4.2	
	Ammonia	91.3	157	65	24.5	21.8	22.3	24.0	25.0	
	Nitrite				0.012	0.003	0.0075	Trace	0.05	
	Nitrate					0.27	0.015	0.1	0.24	
Total Solids, ppm	Total	3592	5587	3627	1611	1581	1472	1578	1625	1928
	Volatile	1071	2045	1757	691	616	690	566	529	599
	Fixed	2521	3542	1870	920	965	882	1012	1096	1329
Suspended Solids, ppm	Total	316	154	206	204	320	312	480	154	170
	Volatile	200	128	202	176	320	292	332	136	162
	Fixed	116	26	4	28	0	20	148	18	8
Chlorides, ppm		340	495	275	128	140	142	148	158	
Sulfates, ppm		37	37.9	0	0	13.6	17	29	47	
Phosphates, ppm		117	203	162	26	27.6	44	23	37	
Others Oil & Grease mg/l			46.6					Detergents 17.3	Detergents 9.3	
Ice			3 ft.	3-1/2 ft.					1 ft.	1-1/2 ft.
Liquid			1 ft.	1/2ft.					1-1/2ft.	2 ft.
Note: Cr. Waste (Creamery Waste)										

CALMAR

The pond system at Calmar serves a population of approximately 600 people, as well as a school enrollment of 526 students, of which 268 are from out of town. The creamery, which produces approximately 1650 lbs. of butter and bottles about 1180 lbs. of milk per day, also uses this pond system. The waste material from the creamery consists mostly of washings from the vats and churns used for their processes as the buttermilk is taken by the surrounding farmers.

This system consists of two ponds, has a total detention period of 64.85 days, with the first pond having a detention time of 4.65 days and the second 60.2 days, thus giving a ratio of approximately 1:13 in volume.

A spot check was made of the pond system at Calmar on December 23rd, 1959, and a composite raw sewage sample was collected in a 24 hour period on December 22nd and 23rd 1959. Measurements of the flow were taken throughout this period of time with a specially designed 90 degree V-notch weir.

		Raw Sewage	Pond No. 1	Pond No. 2
B.O.D. ppm		615	281	172
pH		8.0	7.55	7.8
Alkalinity, ppm		815	880	1065
Millivolts		-68	-42	-60
Odor, T.O.N.		-	-	-
Total Solids, ppm	Total	1940	1526	1594
	Volatile	627	260	216
	Fixed	1313	1266	1378
Suspended Solids ppm	Total	452	86	37
	Volatile	356	79	34
	Fixed	96	7	3
Dissolved Oxygen, ppm		-	0	0
Temperature, °C		-	1.5	0.5

Considering the analysis, the first pond gives a reduction of 54.3% in B.O.D. and the second pond gives an additional 17.7% for a total of 72%. These figures represent a very interesting situation, and as seen above, the biggest reduction occurs in the short detention first pond. At the time these samples were taken, winter conditions existed thus putting more emphasis on the efficiency of short detention ponds as sewage disposal systems.

Efficiency of short detention ponds is a definite asset in considering a sewage pond system design. This efficiency will be shown in most of the other towns where tests were carried out on the short detention ponds.

Water analysis in ppm of the town of Calmar supply from wells.

Average of samples taken on January 15th, 1958 and September 9th, 1959.

Total Solids	1104
Ignition Loss	57
Hardness	81
Sulphates	258
Chlorides	10
Alkalinity	580
Nature of Alkalinity	Bicarbonate of soda, lime and magnesium
Nitrites	Nil
Nitrates	Nil
Iron	0.1

CALMAR

POPULATION - 738 Serving Approximately - 600

Water Consumption - 24,000 gals./day
Sewage Flow - 35,100 gals./day
Number of Connections - 178

SIZE OF PONDS:

Dimensions - Pond #1 - 50' by 135'
- Pond #2 - 109' by 445'

Area - Pond #1 - 0.155 acres
- Pond #2 - 1.11 acres

Capacity - Pond #1 @ 4 ft. depth - 0.1625 million gals.
- Pond #2 @ 7 ft. depth - 2.115 million gals.

Detention Time - Pond #1 - 4.65 days
- Pond #2 - 60.2 days

LOADING:

- Pond #1 - 1390 lbs. B.O.D./acre/day or
348 lbs. B.O.D./acre-ft./day

- Pond #2 - 89 lbs. B.O.D./acre/day or
12.7 lbs. B.O.D./acre-ft./day

B.O.D. Contribution per Capita - 0.360 lbs./day
Sewage Flow per Capita - 58.5 gals./day

DAYSLAND

The short detention pond at Daysland receives a raw domestic sewage from a served population of approximately 350 people and a school population of 350 students of which 210 are from the country. The usual number of business places are connected, with the addition of a creamery. This creamery produces approximately 1100 lbs./day of butter which is not washed at this site. The only waste material from the creamery comes from the washing of the vats and churns as the buttermilk is taken by the surrounding district farmers.

This single pond of 0.0575 acres in size has a detention time of 6.2 days. Studies on this system commenced on September 16th, 1958 and terminated on January 27th, 1960.

Excluding the B.O.D. of 653 ppm on November 18th, 1958, the average B.O.D. of the final effluent was 362 ppm between September 16th, 1958 and January 27th, 1960. Considering the raw sewage B.O.D. to be 702 ppm as of the 24 hour composite sample taken on May 27th and 28th, 1959, the efficiency or percentage reduction was 48.5%. Considering that this is a single pond system and only 6.2 days detention, the efficiency is quite good. With this result it is quite possible to assume that if other short detention ponds were present in series, the reduction of the B.O.D. would be in the same percentage range for each pond , thus bringing the B.O.D. value to a low figure.

As indicated on the data sheet, the pH, alkalinity, total and ammonia nitrogen total and suspended solids, chlorides, sulfates and phosphates were at the same level throughout the whole sampling period. The high sulfate

content, which is present in the water wells in town, had a definite effect upon the odor nuisance in the general area of the pond through the year. This odor was a distinct hydrogen sulfide or rotten egg type which quite possibly came from the reduction of the sulfate compound to the sulfide.

Analysis in ppm of the composite sample of water from individual wells in the town of Daysland:

Total Solids	1574
Ignition Loss	122
Hardness	210
Sulphates	510
Chlorides	14
Alkalinity	595
Nature of Alkalinity	Bicarbonate of soda, lime and magnesium
Nitrites	Nil
Nitrates	Nil
Iron	0.3

DAYSLAND

POPULATION - 507 Serving Approximately - 350

Water Consumption	- Individual water supplies
Sewage Flow	- 15,040 gals./day
Number of Connections	- 100

SIZE OF POND:

Dimensions	- 50' by 50'
Area	- 0.0575 acres
Capacity @ 6 ft. depth	- 0.09345 million gals.
Detention Time	- 6.2 days

LOADING:

2,620 lbs. B.O.D./acre/day or
455 lbs. B.O.D./acre-ft. day
B.O.D. Contribution per Capita - 0.302 lbs./day
Sewage Flow per Capita - 43 gals./day

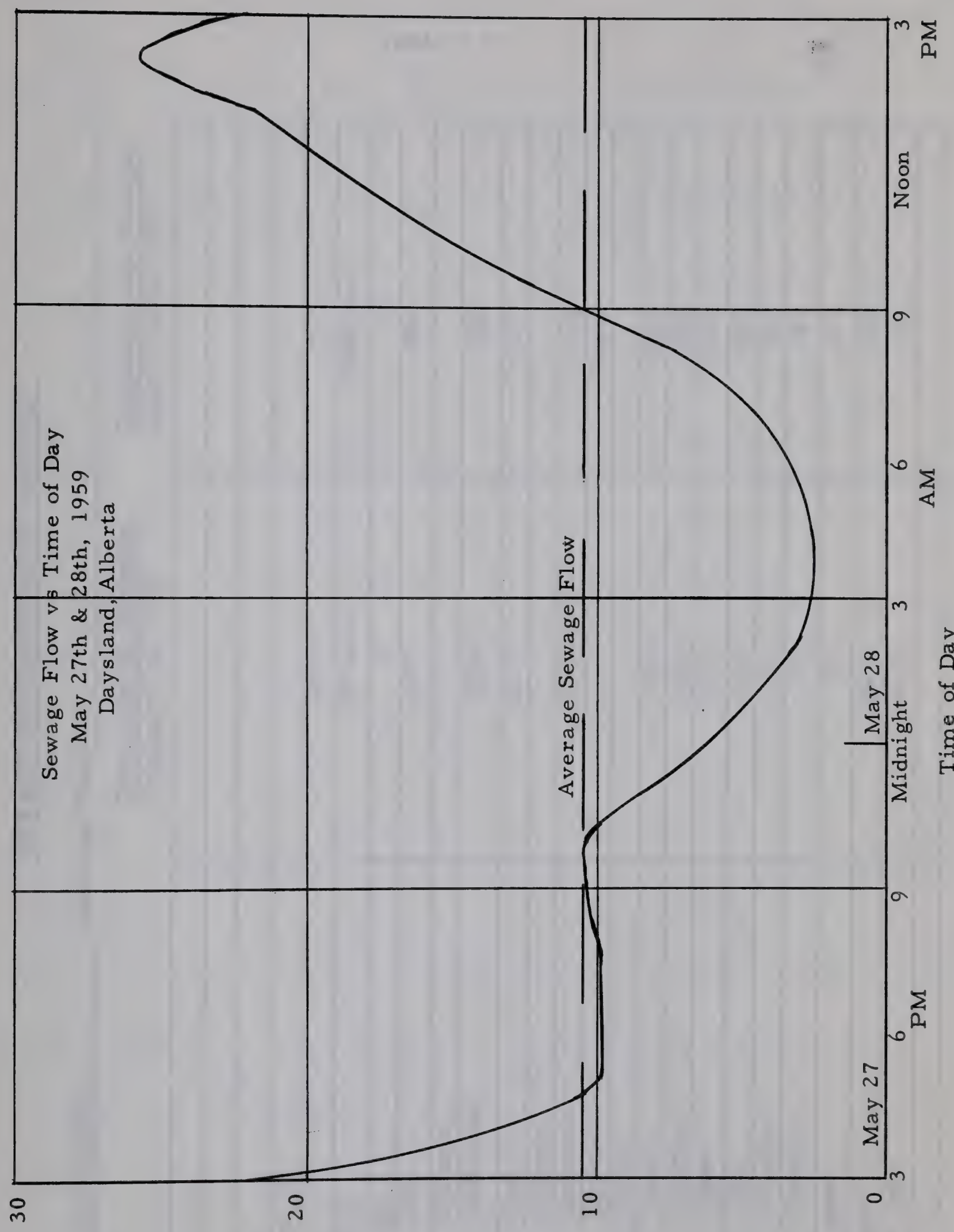

Sewage Flow vs Time of Day
May 27th & 28th, 1959
Daysland, Alberta
Average Sewage Flow
FLOW RATE, Gal./Min.
30
20
10
0
3
6
9
Noon
3
PM
AM
May 27
Midnight
May 28
Time of Day

Figure III

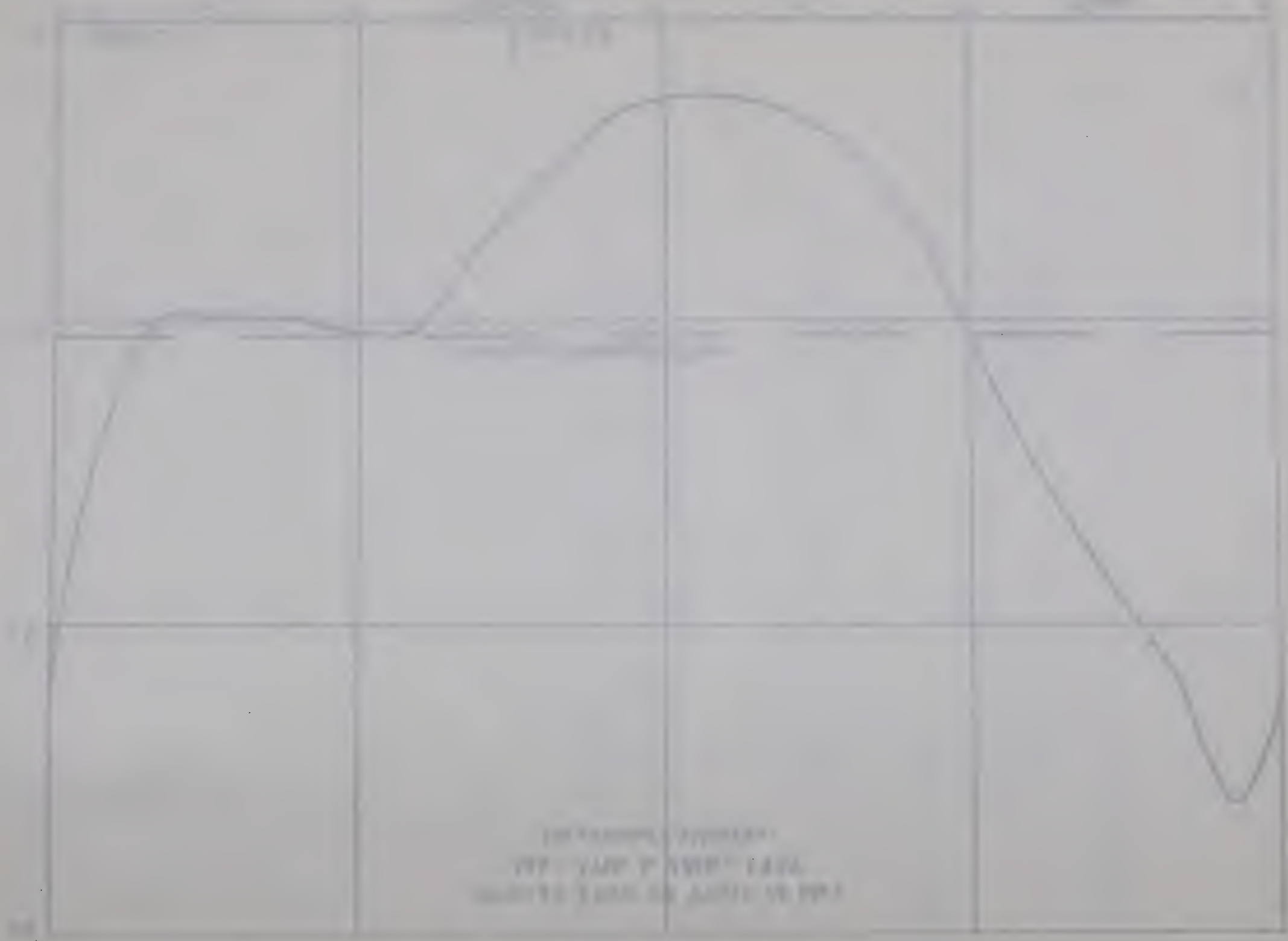


Table V

SEWAGE POND RESEARCH PROJECT

Location: DAYSLAND Sampling Point

Date		Composite Ice Samples February 24, 1959	Composite Raw Sewage May 27 & 28, 1959
Time			
Weather			
D.O. ppm			
Temperature °C			
pH		8.6	7.4
Odor, T.O.N.		250 sew.	9000 sew.
Alkalinity, ppm	pp	5	0
	MO	197	850
B.O.D. ppm	Filtered		
	Unfiltered	274	702
Nitrogens ppm	Total	43.7	50.1
	Organic		
	Ammonia	11.1	42.0
	Nitrite		Trace
	Nitrate		
Total Solids, ppm	Total	807	4066
	Volatile	432	1866
	Fixed	375	2200
Suspended Solids, ppm	Total	182	860
	Volatile	155	776
	Fixed	27	84
Chlorides, ppm		17	114
Sulfates, ppm		46.9	930
Phosphates, ppm		12.9	31
Others			

Inventory Count Sheet

Inventory Date: _____ Inventory Taken By: _____

Item	Quantity in Inventory	Discrepancy (Over/Short)

SEWAGE POND RESEARCH PROJECT

Location: DAYSLAND Sampling Point: 4 ft. in from the N.W. Corner

		1958		1959							1960
Date		Sept. 16	Oct. 21	Nov. 18	Dec. 16	Jan. 20	Feb. 24	Mar. 31	May 28	Sept. 1	Jan. 27
Time		1:30 p.m.	1:15 pm	3:00 pm	3:30 pm	2:30 pm	3:15 pm	12:00	Composite	1:15 pm	12:00 N
Weather		Sunny, Cool & Windy	Sunny Light Winds	Sunny & Warm	Sunny & Cold	Sunny & Cold	Sunny & Warm	Sunny & Cool	Unset-tled	Sunny & Windy	Overcast & Calm
D.O. ppm		0	0	0	0	0	0	0	0	0	0
Temperature °C		15.5	11.5	3	3		3	5	Varied 9 to 10	12	2
pH		7.9	7.8	7.6	7.35	7.4	7.4	7.25	7.7	6.95	7.55
Odor, T.O.N.				15,000 Sewage	10,000 Sewage	5,000 Sewage	10,000 Sewage	20,000 Sewage	4,000 Musty	15,000 H_2S & Sewage	10,000 H_2S & Sewage
Alkalinity ppm	pp	0	0	0	0	0	0	0	0	0	0
ppm	MO	944	1040	1025	925	1035	980	965	1040	1035	915
B.O.D.	Filtered										
ppm	Unfiltered	368	373	653	381	323	319	452	428	283	328
Nitrogens	Total	48.4	63.1	100.7	58.8	80	76.7	74	55.7	45.9	
ppm	Organic								4.2	2.8	
	Ammonia	28.3	34.5	70.8	58.8	79	76.7	76	44.0	25.5	
	Nitrite	0							0	0.01	
	Nitrate	0								0.21	
Total	Total	2542	2615	3214	2368	2175	2140	2270	2575	3074	2295
Solids,	Volatile	683	540	951	439	346	392	451	507	634	397
ppm	Fixed	1959	2075	2263	1929	1829	1748	1819	2068	2440	1898
Suspended	Total	244	144	904	156	188	200	178	220	264	162
Solids,	Volatile	196	106	692	138	160	192	166	208	220	146
ppm	Fixed	48	38	212	18	28	8	12	12	44	16
Chlorides, ppm		101	132	130	118	90	86	125	111	140	
Sulfates, ppm					760	642	649	660	835	1099	
Phosphates					65	51.2	50	57	51	39	
Others				2-1/2" of porous ice contained a lot of susp. organic solids	6" of porous Ice		Oil & gr. 97.6mg/l			Detergents 57.5	
Ice						8"	1'	Open Water			7"
Liquid							3-1/2'				30"
Overflow			Yes	Yes	Yes	Yes	Yes				Yes

DRAYTON VALLEY

The sewage pond system at Drayton Valley consists of three long detention ponds in series. They receive a raw domestic sewage from a served population of approximately 2800 people and the usual number of business places. There are no unusual commercial industries connected which would greatly overload the pond system. It also serves a school population of 900 students of which only 150 are from out of town.

Studies on this system began on October 7th, 1958 and terminated on February 9th, 1960. A composite raw sewage sample was collected in a 24 hour period on September 15th and 16th, 1959, and during this time, measurements of the flow were made by the use of a strong salt solution.

There was a definite difference between summer and winter operations of these ponds as indicated on the data sheets. For pond #1, the average summer B.O.D. was 80 ppm, thus giving a reduction in B.O.D. of 73.5%, and the winter B.O.D. was 132 ppm, giving a reduction of 56.3%. An insufficient number of samples of the effluent from pond #2 prevented a complete pond by pond reduction study of the B.O.D. The final effluent had a B.O.D. of 25 ppm and 107 ppm in the summer and winter respectively, thus giving an additional reduction of 17.7% and 8.2% to bring the total to 91.2% and 64.5% for summer and winter operations respectively. If the influent and effluent of ponds 2 and 3 respectively were considered, this would give reductions of 68.8% and 18.9% for summer and winter reductions respectively across these two units of the ponds.

The above figures show that the summer operation of the pond system (91.2% reduction) is better than the winter operation (64.5% reduction).

This three pond system operates more efficiently in the winter and summer when compared to the single long detention lagoon system at Lacombe.

As indicated on the data sheets, there is a definite increase in pH, and decreases in alkalinity and the total and ammonia nitrogens for the summer samples, with the exact opposite occurring in the winter samples.

There were no odors in the general area around the ponds throughout the summer and fall, but during the spring thaw some odors were noticed. This slight odor can be expected with the spring turnover and the lengths of time for recovery in the spring of 1959 were as follows:

Pond # 1 - 3 weeks Pond # 3 - 1 week

Analysis in ppm of the Drayton Valley town water supply from wells.

Sample taken on August 24th, 1957.

Total Solids	924
Ignition Loss	38
Hardness	35
Sulphates	216
Chlorides	7
Alkalinity	480
Nature of Alkalinity	Bicarbonate of soda, lime and magnesium
Nitrites	Trace
Nitrates	1.6
Iron	0.2

DRAYTON VALLEY

POPULATION - 3821 Serving Approximately - 2800

Water Consumption - 215,000 gals./day
Sewage Flow - 241,900 gals./day
Number of Connections - 533

SIZE OF PONDS:

Area - Pond #1 - 9.2 acres
- Pond #2 - 5.85 acres
- Pond #3 - 7.84 acres

Capacity - Pond #1 @ 5 ft. depth - 12.5 million gals.
- Pond #2 @ 5 ft. depth - 7.95 million gals.
- Pond #3 @ 4 ft. depth - 8.53 million gals.

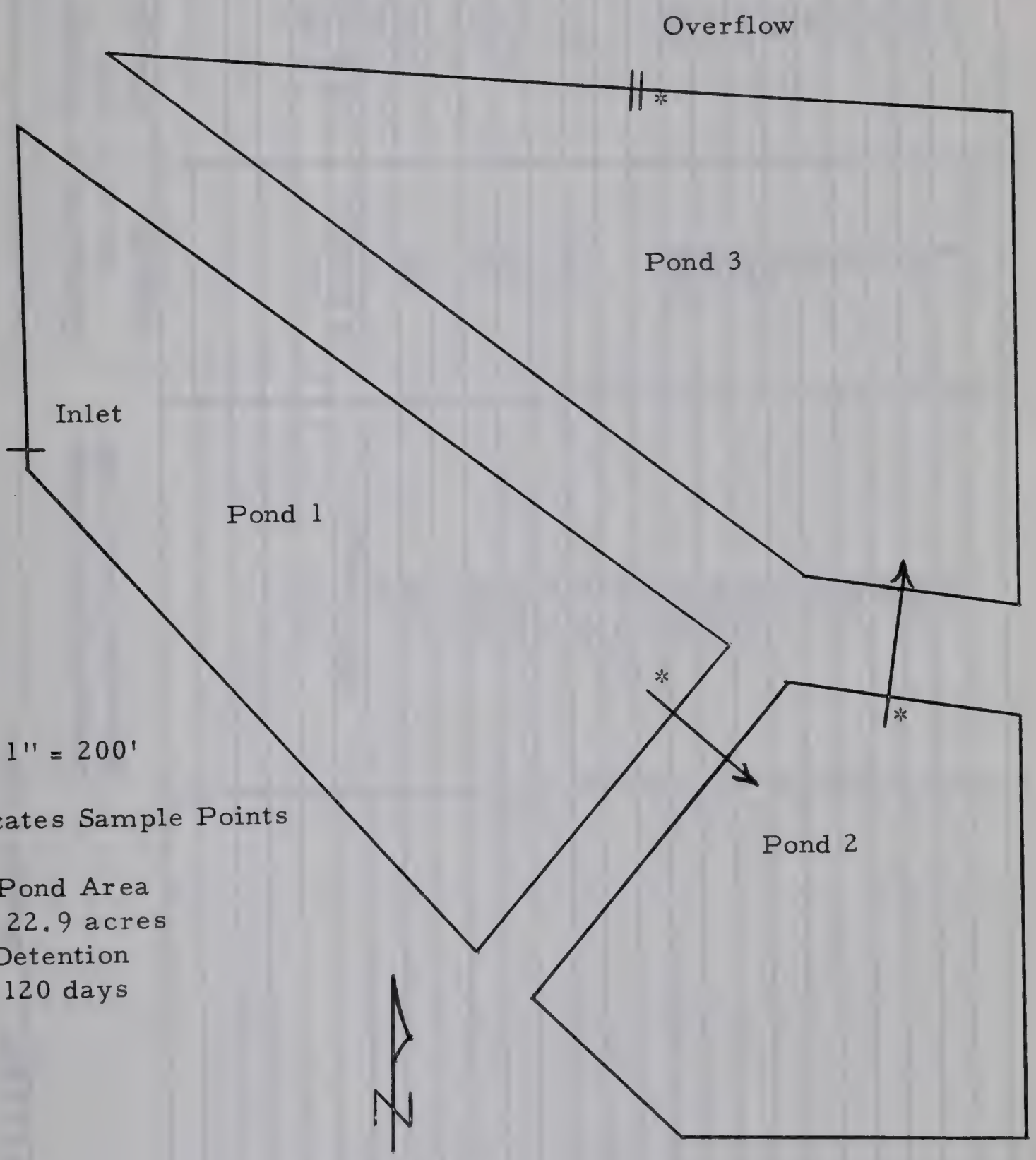
Detention Time - Pond #1 - 51.8 days
- Pond #2 - 32.9 days
- Pond #3 - 35.6 days

LOADING:

Pond #1 - 79.4 lbs. B.O.D./acre/day
Pond #2 - Summer - 33.0 lbs. B.O.D./acre/day
Winter - 54.5 lbs. B.O.D./acre/day
Pond #3 - Insufficient number of samples of effluent from Pond #2
B.O.D. Contribution per Capita - 0.261 lbs./day
Sewage Flow per Capita - 86.3 gals./day

SKETCH OF DRAYTON VALLEY SEWAGE PONDS

Figure IV



Scale: 1" = 200'

* Indicates Sample Points

Total Pond Area
- 22.9 acres

Days Detention
- 120 days

TABLE VI

SEWAGE POND RESEARCH PROJECT

Location: DRAYTON VALLEY Sampling Point: _____

Date		Composite Raw Sewage September 15-16, 1959	Composite Ice Samples March 3, 1959 Pond #1	Pond #3
Time				
Weather				
D.O. ppm				
Temperature °C				
pH		8.2	8.8	8.95
Odor, T.O.N.		4000 Sewage	8 Sewage	10 Sewage
Alkalinity pp		0	7	12
ppm	MO	750	102	167
B.O.D.	Filtered			
ppm	Unfiltered	302	42	23
Nitrogens	Total	42.0	6.2	14.8
ppm	Organic	5.6		
	Ammonia	21.0	1.7	2.5
	Nitrite	Trace		
	Nitrate	0.17		
Total	Total	1594	237	308
Solids	Volatile	454	88	69
ppm	Fixed	1140	149	239
Suspended	Total	532	54	81
Solids	Volatile	272	40	28
ppm	Fixed	260	18	54
Chlorides ppm		64	7	9
Sulfates ppm		252	29	43
Phosphates ppm		34	4	6
Others				

TABLE V

SEWAGE POND RESEARCH PROJECT

Location: DRAYTON VALLEY Sampling Point: Pond #1 Effluent

Date		1958 Oct. 7	1959 Feb. 10	Mar. 3	May 5	Sept. 15 & 16	Dec. 14	1960 Feb. 9
Time		1:30 p.m.	3:15 p.m.	1:30 p.m.		Composite	12:30 p.m.	12:30 p.m.
Weather		Sunny & Cool	Sunny & Cold	Windy & Cold			Overcast & Cold	Overcast & Snowing
D.O. ppm		0.6	0	0		Varied 1.4 to 2.0	0	0
Temperature °C		11	1	1	7.5	12 to 14	1	0.5
pH		8.9	7.45	7.5	7.6	9.1	7.5	7.65
Odor, T.O.N.			750 sewage	1000 & pet.	5000 sewage	64 musty & pet.	1500 sewage	2000 sewage
Alkalinity ppm	pp	36	0	0	0	64	0	0
	MO	659	940	765	642	664	900	910
B.O.D. ppm	Filtered	53						
	Unfiltered	92	118	166	116	34	111	132
Nitrogens ppm	Total	10.6	45.9	40.6	31.1	9.0	37.5	
	Organic					1.7	2.8	
	Ammonia	7.4	38.7	36.0	24.6	2.8	34.0	
	Nitrite				0.045	0.015	0	
	Nitrate					0.33	0.07	
Total Solids ppm	Total	1215	1317	1232	1076	1158	1302	1418
	Volatile	208	249	202	219	194	164	201
	Fixed	1007	1128	1035	857	964	1138	1217
Suspended Solids ppm	Total	126	36	74	76	172	34	46
	Volatile	106	35	48	52	102	34	46
	Fixed	20	1	26	24	70	0	0
Chlorides ppm		34	20	34		42	43	
Sulfates ppm			225	250	179	218	272	
Phosphates ppm			30	27	27	8	21	
Others, Oils & Greases mg/l			54.1			Detergents 14		
Ice			1'	1'			1'	1-1/2'
Liquid		5'	4'		5'	5'	2'	1-1/2'
Overflow		Yes	Yes	Yes	Yes	Yes	No	Yes

TABLE V

SEWAGE POND RESEARCH PROJECT

Location: DRAYTON VALLEY Sampling Point: Pond #2 Effluent

Date		1959 Sept. 15-16	Dec. 14	1960 Feb. 9
Time		Composite	12:15 pm	12:00 N
Weather			Overcast & Cold	Overcast & Snowing
D.O. ppm		Varied 0.5 to 4.5	0	0
Temperature °C		11.5-14	1	0.5
pH		9.1	7.65	7.9
Odor, T.O.N.		16 musty	1500 sewage	1000 sewage
Akalinity	pp	66	0	0
ppm	MO	666	895	1165
B.O.D.	Filtered			
ppm	Unfiltered	19	86	78
Nitrogens	Total	5.6	33.0	
ppm	Organic	1.7	2.8	
	Ammonia	2.0	28.3	
	Nitrite	0.025	0	
	Nitrate	0.07	0.14	
Total	Total	1074	1343	1855
Solids	Volatile	143	165	292
ppm	Fixed	931	1178	1563
Suspended	Total	80	47	56
Solids	Volatile	36	44	52
ppm	Fixed	44	3	4
Chlorides	ppm	42	43	Bypassing
Sulfates	ppm	205	286	#2 pond
Phosphates	ppm	7	19	
Others	Detergents	7		
Ice			1'	1-1/2'
Liquid		5'	2'	1-1/2'
Overflow		Yes	No	No

TABLE V

SEWAGE POND RESEARCH PROJECT

Location: DRAYTON VALLEY Sampling Point: Final Effluent

Date:		1958 Oct. 7	1959 Feb. 10	Mar. 3	May 5	Sept. 15 & 16	Dec. 14	1960 Feb. 9
Time		2:00 p.m.	12:45 p.m.	2:30 p.m.		Composite	11:45 a.m.	11:30 a.m.
Weather		Sunny & Cool	Sunny & Cold	Windy & Cold			Overcast & Cold	Overcast & Snowing
D.O. ppm		11.3	0	0		Varied 1.4 to 7.3	0	0
Temperature °C		10	1	1	6	11 to 13	1	0.5
pH		9.6	7.6	7.7	7.7	8.55	7.95	7.6
Odor, T.O.N.			1500 sewage	1000 & Petrol	1000 sewage	8 musty	100 sewage & musty	500 sewage
Alkalinity ppm	pp	150	0	0	0	17	0	0
	MO	795	1200	1000	515	717	895	800
B.O.D. ppm	Filtered							
	Unfiltered	45	107	146	24	6	38	135
Nitrogens ppm	Total	Trace	43.4	45.1	14.6	5.9	22.1	
	Organic					1.1	0.3	
	Ammonia	Trace	40.1	40.0	12.7	1.8	20.5	
	Nitrite				0.018	Trace	0	
	Nitrate					Trace	0.12	
Total Solids ppm	Total	1008	1862	1456	742	1052	1317	1358
	Volatile	111		190	129	125	135	250
	Fixed	897		1266	613	927	1182	1108
Suspended Solids ppm	Total	41	18	50	42	48	33	40
	Volatile	20	18	30	34	14	28	40
	Fixed	21	0	20	8	34	5	0
Chlorides, ppm		34	26	24		38	43	
Sulfates ppm			286	266	125	163	256	
Phosphates ppm			43	32	17	4	21	
Others Oils & Grease mg/l			22.3			Detergents 6		
Ice			2'	2'			1'	1-1/2'
Liquid		4'	2'	2'	4'	4'	2-1/2'	3'
Overflow		Yes	Yes	Yes	Yes	Yes	No	No

HOLDEN

The aerobic sewage pond of 7.2 acres at Holden receives a raw domestic sewage from a served population of approximately 450 people. It also serves a school of approximately 600 students, of which 500 come from the country and as well it serves a creamery which produces, on the average, 1780 lbs. of butter per day. The waste from the creamery consists mainly of washings of the vats and churns as the butter is not washed at the site and the buttermilk is taken by the farmers.

Studies on the pond commenced on May 20th, 1958 and terminated on April 14th, 1960. Raw sewage composite samples were collected during 24 hour periods on June 24th - 25th, 1958, March 2nd - 3rd, 1960 and April 13th - 14th, 1960. During the 24 hour period of May 26th and 27th, 1959, measurements of the sewage flow were made by the use of a recording ammeter hooked up on the power inlet to the pump. By this method very accurate measurements of the sewage flow were obtained.

The B.O.D.'s of the summer samples from the pond in 1958 and 1959 remained at an average of 85.5 ppm, giving a B.O.D. removal of 82.5%. The winter samples had an average B.O.D. of 133 ppm, giving a B.O.D. removal of 72.5%. This low winter average B.O.D. is accounted for by the fact that the B.O.D. did not rise as soon as the ice cover formed as compared to Lacombe. It was not until three months later that the B.O.D. rose appreciably (from 103 ppm on January 6, 1959 to 200 ppm on February 4, 1959), whereas the Lacombe B.O.D. increased 100% plus in one month after ice cover.

Corrected B.O.D.'s for the winter samples were made giving an average B.O.D. of 91.6 ppm, thus, a removal of 81.1%. These corrections were made by considering the summer and winter total solids and multiplying the fraction times the B.O.D. By this method a theoretical picture of the treatment is given where a thick layer of ice is obtained giving a considerable smaller volume of liquid. These corrections are shown on the data sheets.

Samples of January 6th and February 4th, 1959 showed significant increases in odor, alkalinity, total and ammonia nitrogens, total solids, chloride and phosphate and at the same time a significant decrease in pH resulted during this period.

The total and ammonia nitrogen tests were begun in the late summer of 1958 and continued in all of the subsequent samples. The concentrations remained low in all summer (1958 and 1959) samples and winter samples showed a definite and simultaneous increase till a maximum was obtained in March. The nitrite and nitrate nitrogens were low whenever they were tested. Corrections were also made for the winter total nitrogens and are shown on the data sheet.

There was a definite difference in phosphate content between the summer and winter samples and once again as for Lacombe, the variations were associated with the pH change. Correction of the phosphates were made as well and also shown on the data sheet.

Total solids, chlorides and sulfates content remained at the same level throughout the summer, and the winter samples showed an increase which was mostly due to freezing of the liquid. Suspended solids, as in other places,

showed variations in the summer which were mostly due to the weather conditions (variations in wind speeds). At the present time, no definite explanation is available for the considerable difference in concentration of chloride and sulfate contents between the pond and water supply concentrations, but it is quite possible that leaching of the soil occurs.

The pond recovery in the spring of 1959 took a total time of approximately eight weeks. This extended time was mostly due to hydrogen sulfide odor which was initially detected in the February sample. With the high sulfate content at the beginning of the winter, it is quite likely that the sulfate was reduced to the sulfide.

This pond is operated with two draw downs a year, which are timed so that no greater nuisance than necessary is created. The absence of a good drainage course makes it necessary for extreme care in the draw down time of the pond and does not permit a continuous overflow in the summer.

Water analysis, in ppm, of the treated Holden surface supply taken on July 7, 1958.

Total Solids	660
Ignition Loss	160
Hardness	220
Sulphates	149
Chlorides	14
Alkalinity	305
Nature of Alkalinity	Bicarbonate of soda, lime and magnesium
Nitrites	Nil
Nitrates	Nil
Iron	1.5

HOLDEN

POPULATION - 547 Serving Approximately - 450

Water Consumption - 20,000 gals./day
Sewage Flow - 28,500 gals./day
Number of Connections - 160

SIZE OF POND:

Dimensions - 560' by 560'
Area - 7.2 acres
Capacity @ 4 ft. depth - 7.82 million gals.
Detention Time - 274 days

LOADING:

19.2 lbs. B.O.D./acre/day
B.O.D. Contribution per Capita - 0.308 lbs./day
Sewage Flow per Capita - 63.4 gals./day

SKETCH OF HOLDEN SEWAGE POND

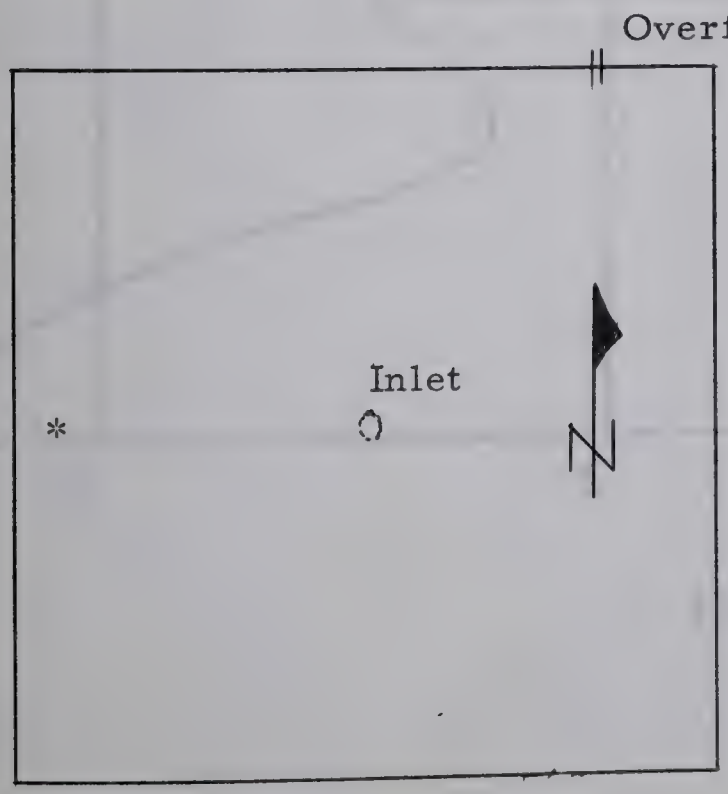


Figure V

Scale: 1" = 200'

* Indicates Sample Point

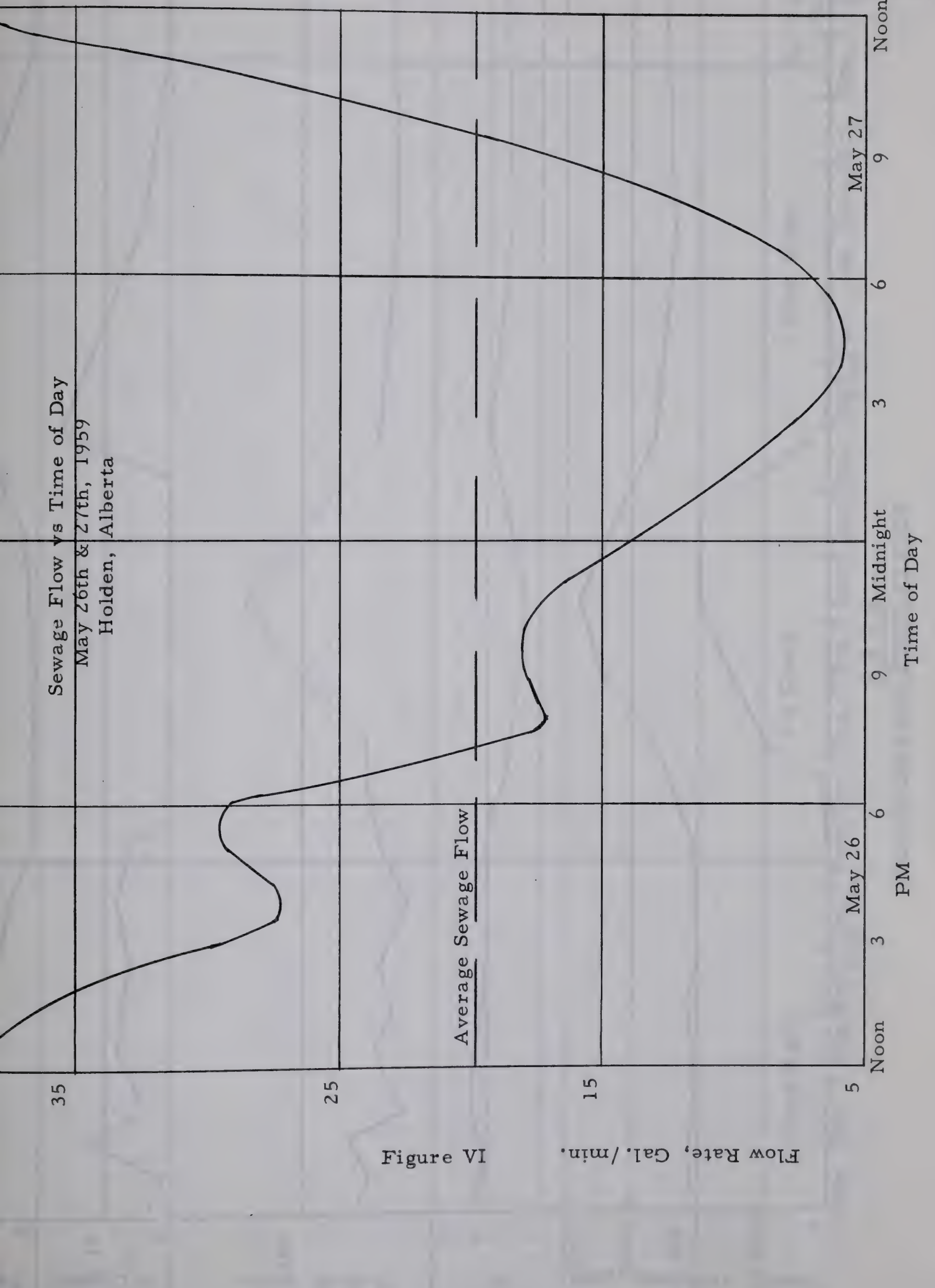
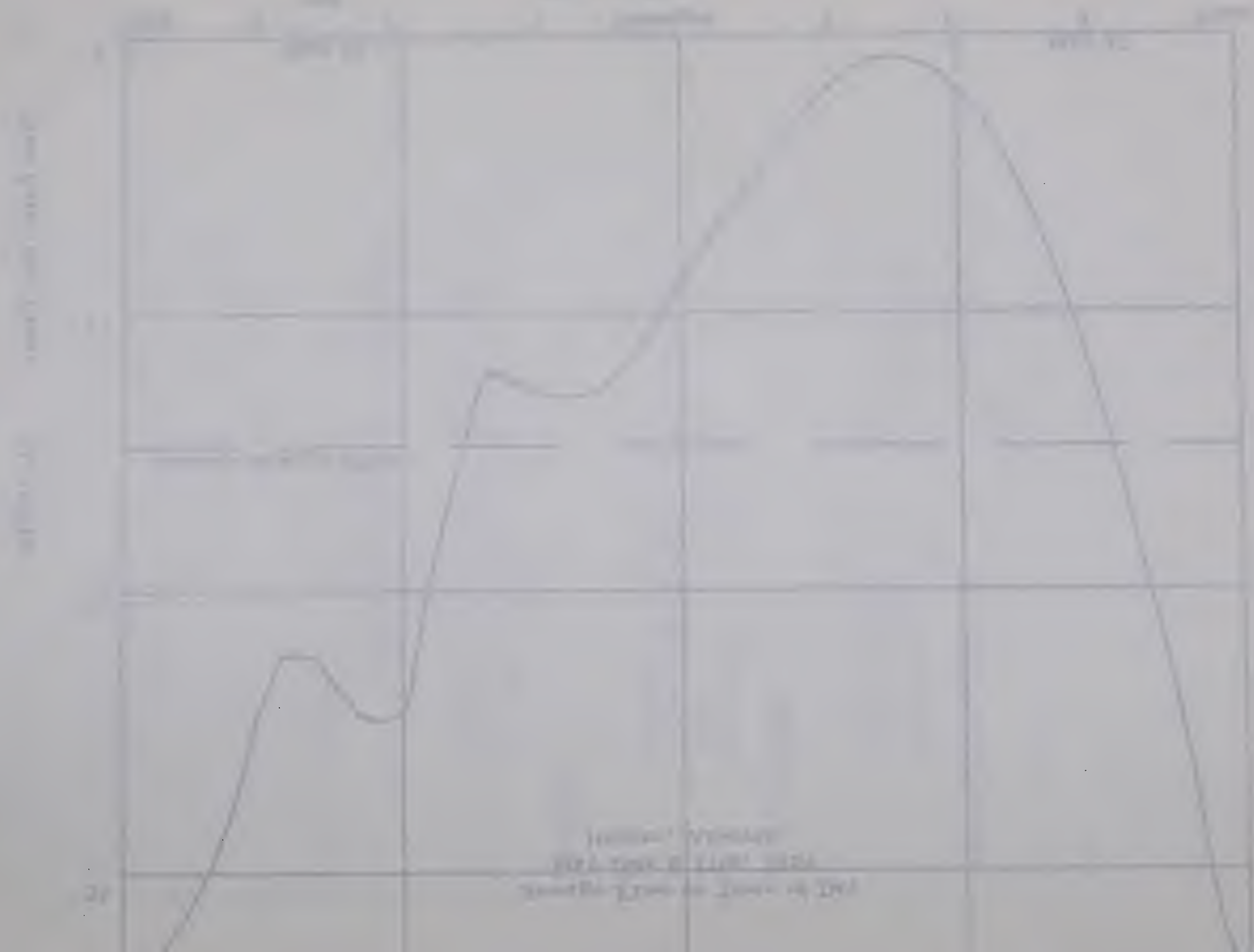

Sewage Flow vs Time of Day
May 26th & 27th, 1959
Holden, Alberta
Average Sewage Flow
Flow Rate, Gal./min.
35
25
15
5
Noon
3
6
9
Midnight
3
6
9
Noon
May 26
May 27
PM
Time of Day

Figure VI



Temp. 0

D.O. ppm. 15 0

B.O.D. ppm. 200

0

pH 9 7

Odor, T.O.N. 2600

Alkal., ppm 1600 600

10000

0

Open Water | Ice Cover | Open Water | Ice Cover

June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.

1958 1959 1960

DATE

HOLDEN SEWAGE POND TRENDS

T. S. ppm.
5500
4500
3500
2500

V. S. S. ppm.
200
0

Total N, ppm
50
0

NH_3-N, ppm
50
0

PO_4, ppm.
50
0

SO_4, ppm.
1800
1200
600

Open Water
Ice Cover
Open Water
Ice Cover

June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1958 1959 1960

DATE

HOLDEN SEWAGE POND TRENDS

Figure VII

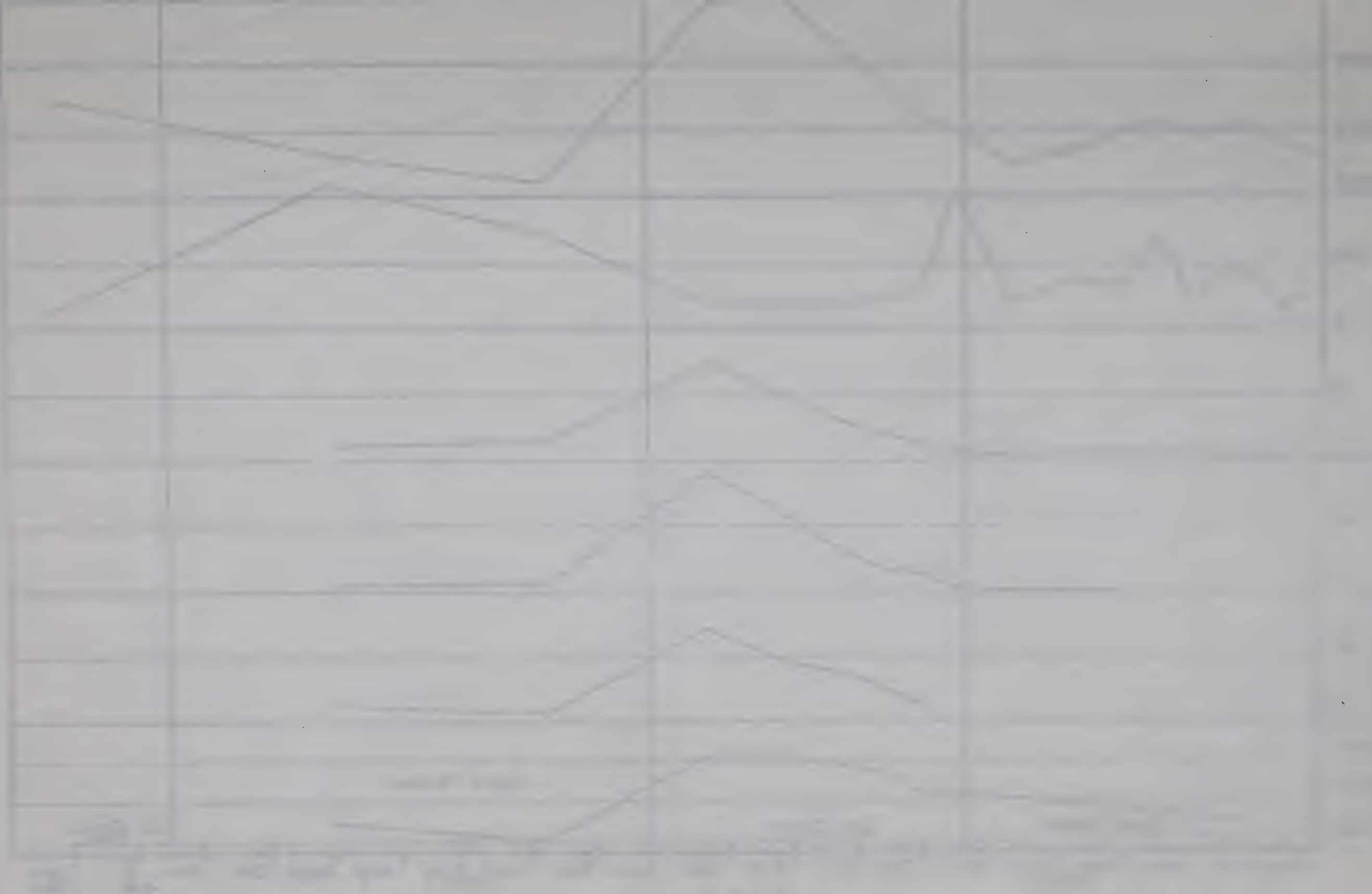


TABLE VII

SEWAGE POND RESEARCH PROJECT

Location: HOLDEN Sampling Point:

		Composite Ice Samples		Composite Raw Sewage	
		1959	1958	1960	
Date		February 24	June 24 & 25	March 2 & 3	April 13 & 14
Time					
Weather					
D.O. ppm					
Temperature °C					
pH		8.55		8.1	8.0
Odor, T.O.N.		32 slough water		2000 sewage	1000 sewage
Alkalinity ppm	pp	6		0	0
ppm	MO	196		750	655
B.O.D.	Filtered				
ppm	Unfiltered	26.6	260	460	510
Nitrogens	Total	3.7	32	67.2	55
ppm	Organic			7.7	13
	Ammonia	4.6		71.0	56
	Nitrite		0.095	0	Trace
	Nitrate		0.045	0.5	0.4
Total	Total	677	2789	2424	2681
Solids,	Volatile	153	481	652	950
ppm	Fixed	524	2308	1772	1731
Suspended	Total	34	238	324	630
Solids,	Volatile	30	115	276	552
ppm	Fixed	4	123	48	78
Chlorides ppm		59		101	60
Sulfates ppm		224		785	800
Phosphates ppm		5.7		44	32
Others					

TABLE VII

SEWAGE POND RESEARCH PROJECT

Location: HOLDEN Sampling Point: 40 ft. from west edge - 1/2 way between north and south edges of lagoon

Date: 1958		May 20	May 28	June 4	June 17	July 4	July 18	July 30	Aug. 15	Sept. 3	Sept. 24
Time		2:00 pm	1:30 pm	11:30am	11:00am	11:15am	11:15am	11:00am	11:30am	11:45am	10:45am
Weather		Sunny & Warm	Over-Cast Windy	Cloudy	Cloudy & Calm	Sunny & Cloudy & Windy	Sunny & Windy & Warm	Hot & Clear	Sunny & Warm	Fine & Light Wind	Fine & Strong Wind
D.O. ppm		14.3	20.9	4.7	1.9	18.8	6.5		12.8		10.2
Temperature °C		16.5	18	17.5	20	20	24	20	22.5	14	9
pH		9.2		9.4	9.1	9.3	9.55	9.6	9.4	9.2	9.1
Odor, T.O.N.											
Alkalinity ppm	pp			155	117	139	165	156	162	118	63
ppm	MO			698	731	734	662	645	680	741	605
B.O.D.	Filtered					46	20.1	46.2		21.2	54.8
ppm	Unfiltered	104.5	137.2	115	95.3	131	42	71.6	88.4	63.0	81
Nitrogens	Total	13.7	9.0		4.2					7.0	
ppm	Organic										
	Ammonia									0	
	Nitrite				0.2						
	Nitrate										
Total	Total	3263	3242	3073	3307	3538	3474	3392	3628	3498	3209
Solids,	Volatile	636	646	571	658	708	640	618	647	572	448
ppm	Fixed	2627	2596	2502	2649	2830	2834	2774	2981	2926	2761
Suspended	Total	204	230	114	64	180	160	72	275	120	156
Solids	Volatile	169	196	104	50	89	96	66	164	100	90
ppm	Fixed	35	34	10	14	91	64	6	111	20	66
Chlorides	ppm					340				365	
Sulfates	ppm					906					
Phosphates	ppm										
Others											

TABLE VII

SEWAGE POND RESEARCH PROJECT

Location: HOLDEN Sampling Point: 40 ft. from W. edge

Date		1958 Oct. 21	Nov. 18	Dec. 2	1959 Dec. 16	Jan. 6	Feb. 4	Mar. 10	May 26 & 27	Sept. 1	1960 Jan. 6
Time		11:30am	12:00N	11:30am	11:45am	12:00N	11:15am	12:30pm	Composite	12:15pm	11:45 am
Weather		Sunny & Light Wind	Sunny & Warm	Sunny & Cold	Sunny & Cold	Sunny & Cold	Sunny & Cold	Sunny & Warm		Sunny & Light Wind	Sunny & Windy
D.O. ppm		12.2	9.7	0	0	0	0	0	24	6.6	0
Temperature °C		7	1	1	1	0.5	0.5		12 to 15	14	0.5
pH		9.0	9.1	8.8	8.35	8.1	7.85	7.6	8.9	8.1	8.25
Odor, T.O.N.			32	100 Slough	1500 sewage	10,000 sewage	15,000 sewage	20,000 H_2S	3000 musty	12 musty	
Alkalinity ppm	pp	65	84	69	15	0	0	0	105	0	0
	MO	619	676	820	1015	1240	2085	2400	1070	980	1160
B.O.D. ppm	Filtered	12.9	41.3	32.2	63.8	82.5				13.4	
	Unfiltered	40.1	81.4	93.1	101.3	103.2	200	290	84	58.5	63
Nitrogens ppm	Total	4.8	7.8		19.0	29.4	50.4	74.2	14.0	9.8	
	Organic								5.0	3.4	
	Ammonia	0	2.5	11.2	14.8	28.5	59	90.5	4.8	2.4	
	Nitrite								0.033	0.025	
	Nitrate									0.5	
Total Solids, ppm	Total	3070	3610	3626	4248	4674	5524	5475	2718	3151	4024
	Volatile	637	612	598	612	637	725	790	582	718	579
	Fixed	2433	2998	3028	3636	4037	4799	4685	2131	2433	3445
Suspended Solids ppm	Total	82	320	140	44	39	37	38	288	340	50
	Volatile	60	180	80	44	34	31	38	232	260	44
	Fixed	27	140	60	0	5	6	0	56	80	6
Chlorides	ppm	360	370	393	465	515	620	595	268	280	
Sulfates	ppm		1366	1360	1620		1922	1850	625	905	
Phosphates	ppm			14.4	25.4	35	48	72	7.3	14.7	
Others Oils & Grease mg/l							46.3			Detergent 20.2	
Ice			4"	10"	15"	18"	18"	24"			24"
Liquid Overflow		No	8" No	6" No	8" No	8" No	12" No	18" No	No	No	16" No

TABLE VII

SEWAGE POND RESEARCH PROJECT

Location: HOLDEN Sampling Point: Corrections for winter samples for B.O.D., total N & PO_4

Date		1958 Nov. 18	Dec. 2	Dec. 16	1959 Jan. 6	Feb. 4	Mar. 10	1960 Jan. 6
Time								
Weather								
D.O. ppm								
Temperature °C								
pH								
Odor, T.O.N.								
Alkalinity	pp							
ppm	MO							
B.O.D.	Filtered							
ppm	Unfiltered	73.6	84.1	78.2	72.2	118.6	173.4	41.3
Nitrogens	Total	7.1		14.7	20.6	29.9	44.4	
ppm	Organic							
	Ammonia							
	Nitrite							
	Nitrate							
Total	Total							
Solids,	Volatile							
ppm	Fixed							
Suspended	Total							
Solids	Volatile							
ppm	Fixed							
Chlorides	ppm							
Sulfates	ppm							
Phosphates			13.0	19.6	24.5	28.5	43.1	
Others								

LACOMBE

This aerobic sewage pond of 16.64 acres receives a raw domestic sewage from a served population of 2,835 people. It also serves a school of 1,236 students, of which about one half are from the country. There are the usual number of business places, but no unusual commercial industries which would overload the pond.

Studies on this pond commenced on June 6th, 1958 and terminated on January 14th, 1960. A composite raw sewage sample was collected during a 24 hour period on December 29th and 30th, 1958, and during this period measurements of the flow were made by timing the pumping time as well as the fill up time of the lift station wet well. By this method of checking the flow, a very accurate measurement was obtained.

The B.O.D. of the pond was found to be low during the summers of 1958 and 1959. Following the 1958 summer when the ice cover came on at approximately the middle of November, a remarkable increase in the B.O.D. was obtained. This rapid increase occurred in a very short period of time, between November 25th and December 9th, 1959. The average summer B.O.D. was 59 ppm, giving a reduction of 82.5%, while winter samples gave a B.O.D. of 208 ppm, for a reduction of only 38.5%. There was no overflow during the winter months (November, 1958 to March, 1959) and at the time when the overflow started in March, the B.O.D. of the effluent was 155 ppm, or a reduction of 54.1%. The spring recovery in 1959 took approximately three to four weeks before the odor in the general area disappeared.

The total and ammonia nitrogen tests were begun in the late summer of 1958 and the trend was a slow increase in the fall until a large increase occurred about the same time as the increase in B.O.D. was recorded. This high concentration remained throughout the winter and once again the summer (1959) samples had low concentrations. Whenever the nitrite and nitrate nitrogen tests were run they were quite low.

The average concentration of phosphate in the winter samples was 48.3 ppm and for the summer 29.3 ppm. This difference could be accounted for by considering the average winter and summer pH of 7.5 and 8.9 respectively. The higher summer pH may have caused a precipitation of the phosphate which is more marked in other lagoons rather than this one.

Suspended solids concentrations in the summer are governed by the amount of wind, thus mixing up of the bottom sludge, and in the winter by the amount of liquid under the icewhen a hole is cut out. The suction obtained when the hole is broken through might have brought along some bottom sludge if the liquid level was too thin.

During the times the marked increases in B.O.D. and nitrogens (total and ammonia) occurred a decrease in pH, and a large increase in the alkalinity were also noticed. This shows that there must be definite correlation between the commodities which either decreased or increased in such a short length of time.

This pond is operated with a continuous overflow throughout the summer and for the winter it is drawn down in November. The draw down is to such a point so that the lagoon does not fill up until late March or April when again a continuous overflow is used. The overflow enters a constructed drainage ditch

for a few miles which in turn enters a natural drainage course, finally ending up in the Battle River. Samples taken from the constructed drainage ditch at various points showed that the B.O.D. and ammonia nitrogen declined in concentration in a very short distance.

Water analysis, in ppm of the Lacombe town supply taken from wells on November 25th, 1958:

Total Solids	546
Ignition Loss	86
Hardness	115
Sulphates	Nil
Chlorides	10
Alkalinity	460
Nature of Alkalinity	Bicarbonate of soda, lime and magnesium
Nitrites	Nil
Nitrates	Nil
Iron	Nil

LACOME

POPULATION - 2923 Serving Approximately - 2835

Water Consumption - 114,000 gals./day
Sewage Flow - 110,600 gals./day
Number of Connections - 825

SIZE OF POND:

Dimensions - approximately 1100' by 700'
Area - 16.64 acres
Capacity @ 5 ft. depth - 22.6 million gals.
Detention Time - 204.4 days

LOADING:

22.43 lbs. B.O.D./acre/day
B.O.D. Contribution per Capita - 0.132 lbs./day
Sewage Flow per Capita - 39.1 gals./day

SKETCH OF LACOMBE SEWAGE POND

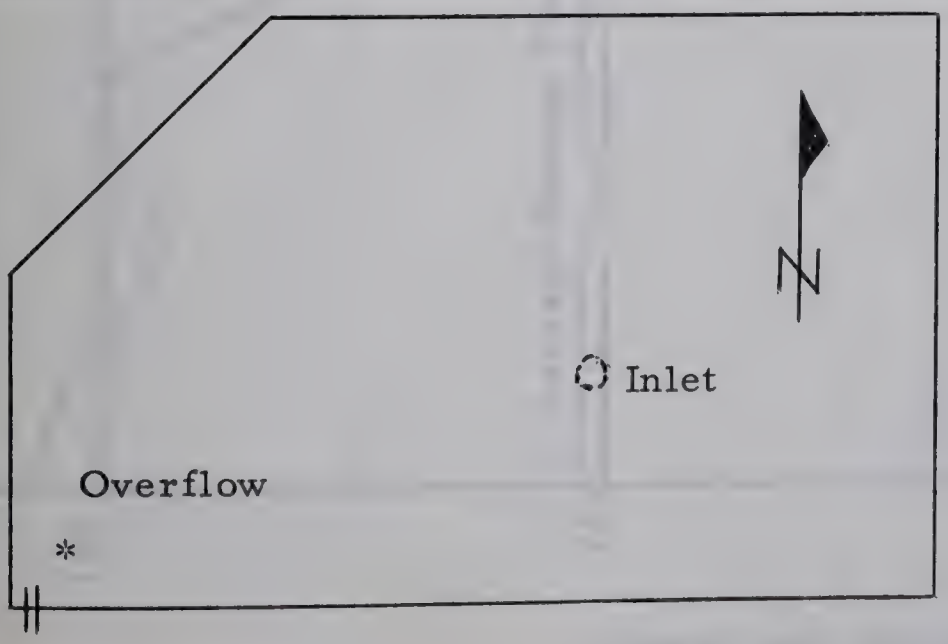


Figure VIII

Scale: 3/4" = 100'

* Indicates Sample Point

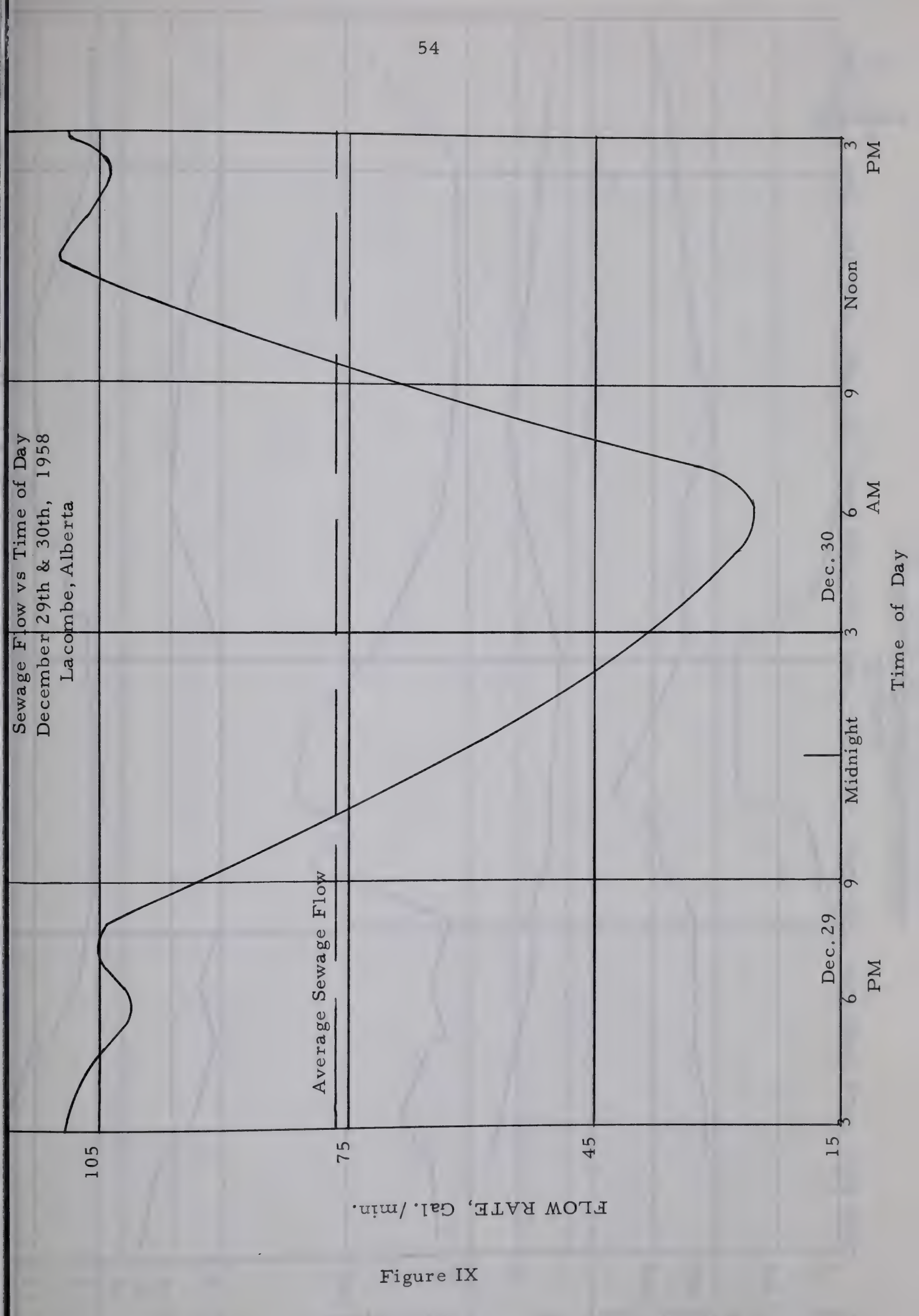
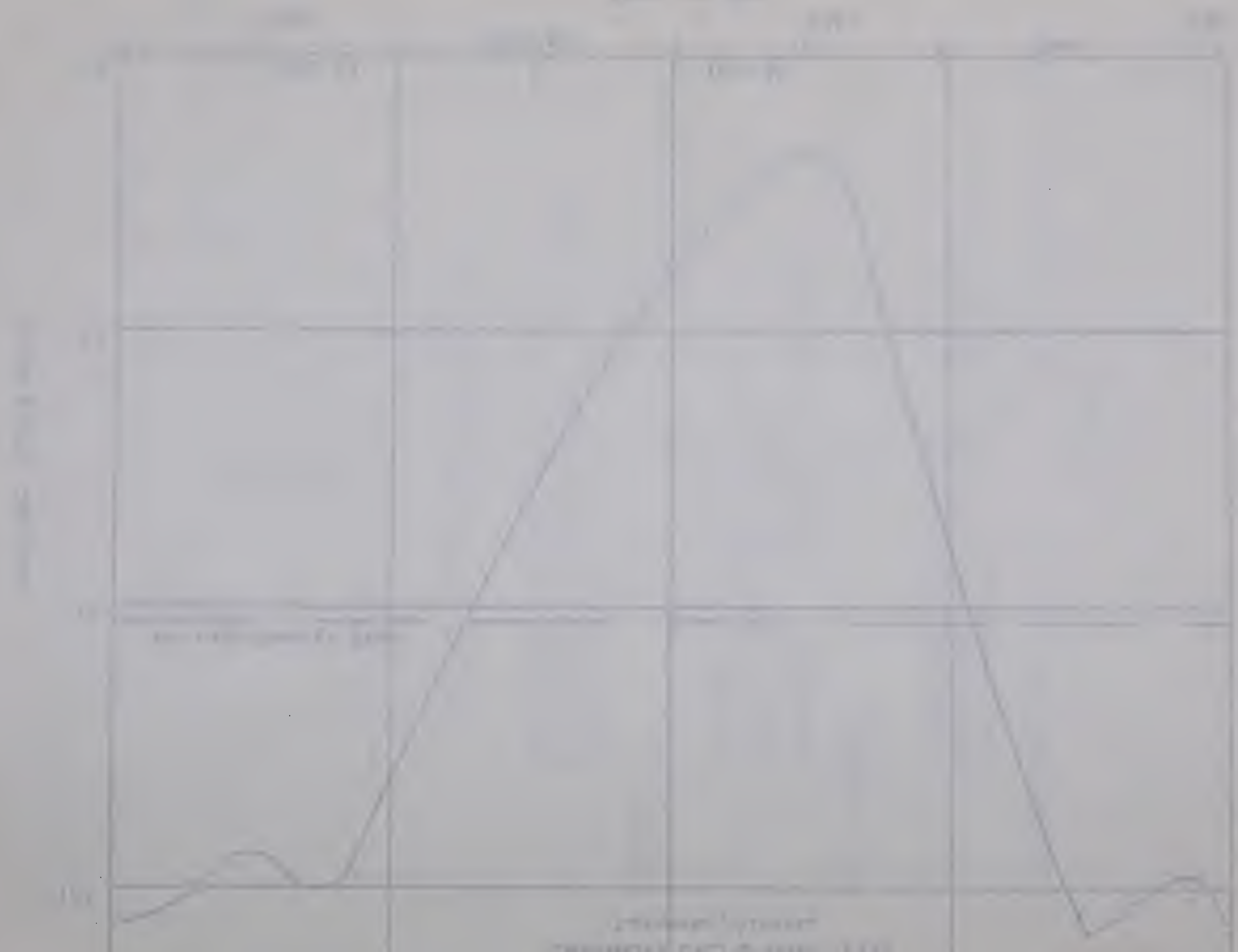

Sewage Flow vs Time of Day
December 29th & 30th, 1958
Lacombe, Alberta
FLOW RATE, Gal./min.
105
75
45
15
Average Sewage Flow
3
6
9
Noon
3
PM
Dec. 30
AM
Dec. 29
PM
Midnight
Time of Day

Figure IX



Temp. 15 0

D.O.ppm. 40 20 0

B.O.D. ppm. 200 0

pH 9 7

Alkal., ppm 1000 500

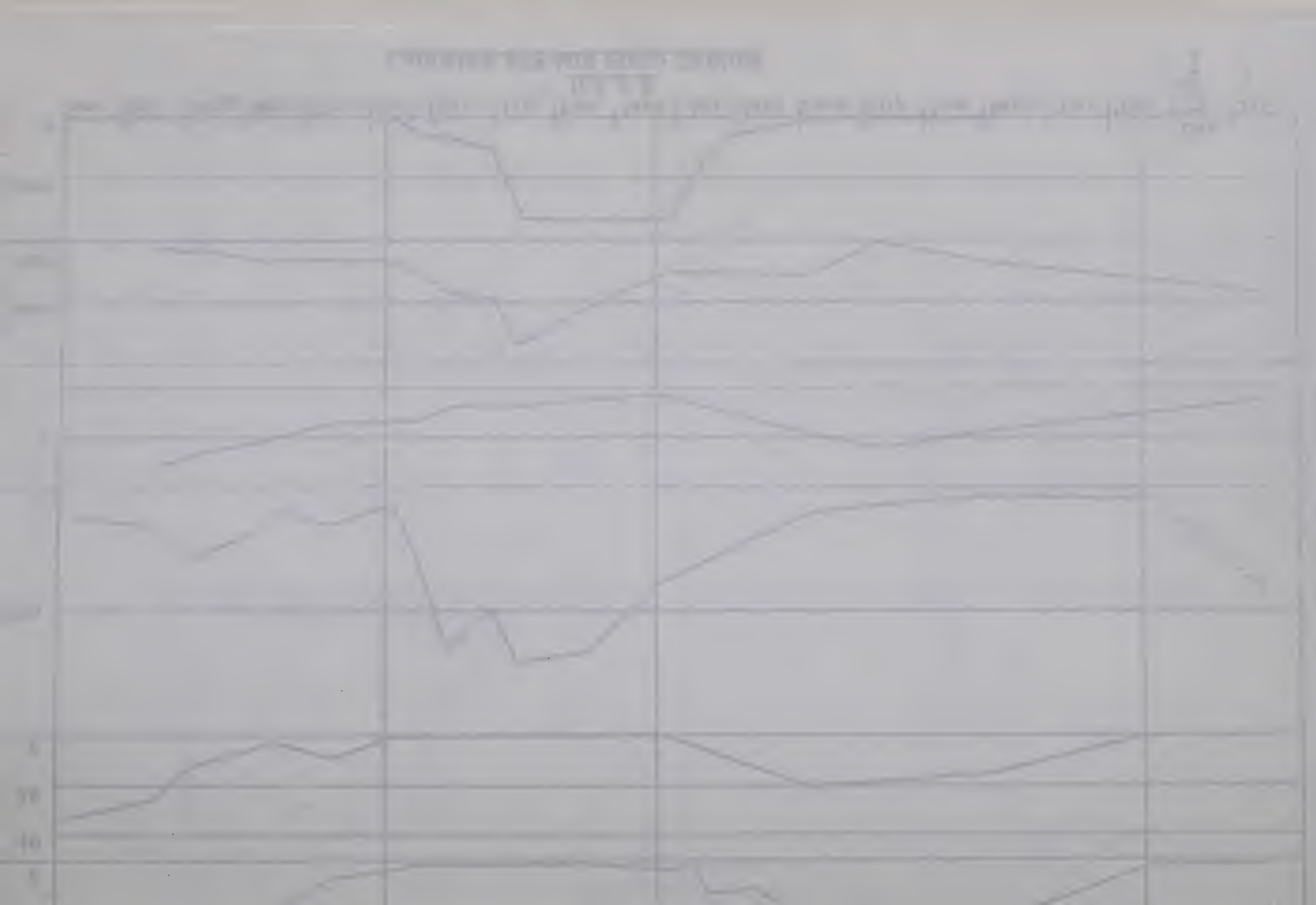
Odor, T.O.N. 1500 0

June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.

DATE

LACOMBE SEWAGE POND TRENDS

Figure X



T.S.p
1000
S.S., ppm.
200
0
Total N, ppm
50
0
NH_3-N, ppm
50
0
PO_4, ppm.
60
30
SO_4, ppm.
60
30
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1958 1959 1960
DATE

Figure X

LACOMBE SEWAGE POND TRENDS

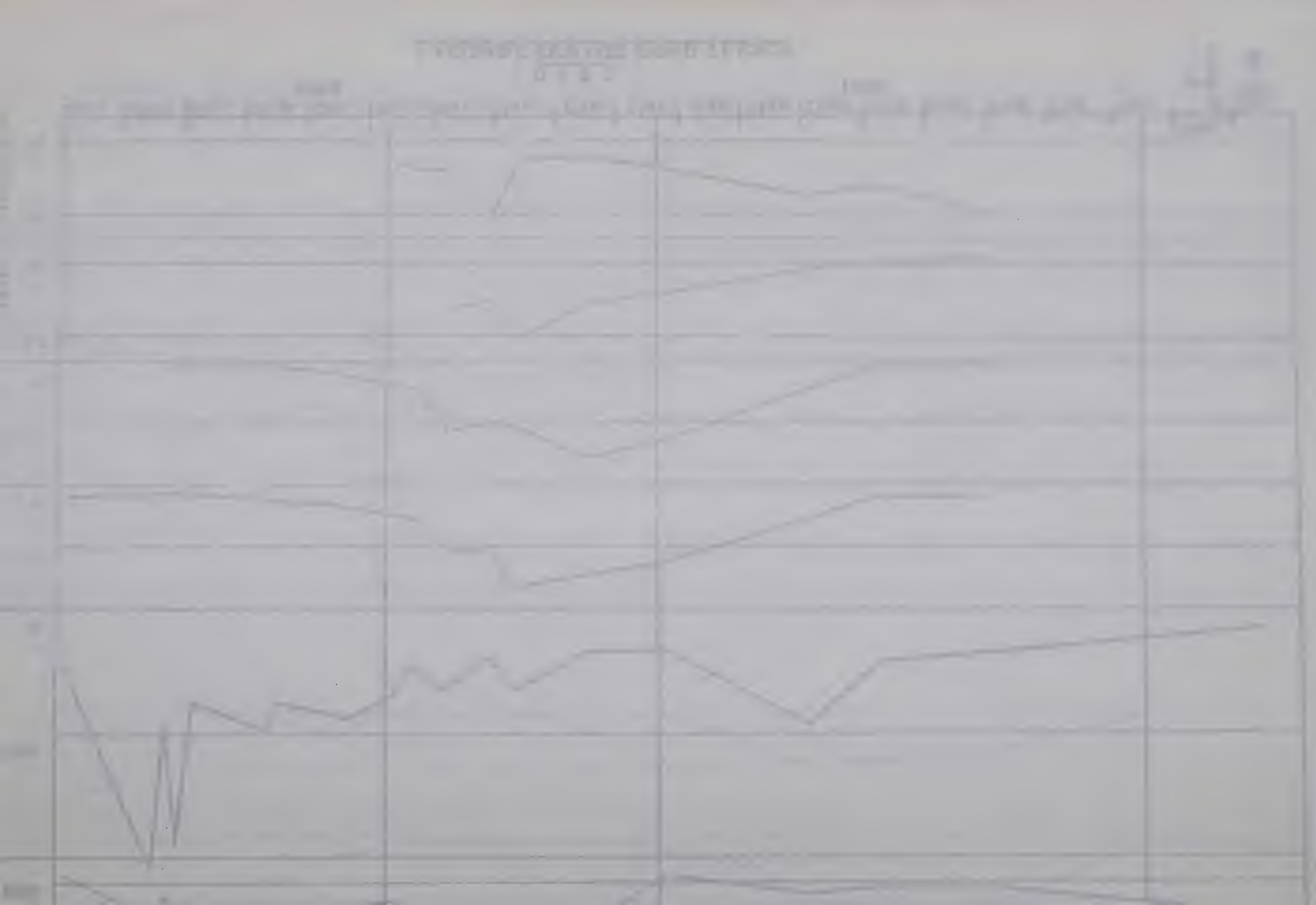


TABLE VIII

SEWAGE POND RESEARCH PROJECT

Location: LACOMBE Sampling Point:

Date		Composite Raw Sewage December 29 & 30, 1958	Composite Ice Samples February 17, 1959
Time			
Weather			
D.O. ppm			
Temperature °C			
pH		7.8	8.65
Odor, T.O.N.		5000 sewage	16 sewage
Alkalinity pp		0	1
ppm	MO	711	110
B.O.D.	Filtered		
ppm	Unfiltered	338	40
Nitrogens	Total	80.4	5.2
ppm	Organic		
	Ammonia	47.9	5.1
	Nitrite		
	Nitrate		
Total	Total	1117	199
Solids	Volatile	374	66
ppm	Fixed	643	133
Suspended	Total	204	49
Solids	Volatile	200	35
ppm	Fixed	4	14
Chlorides ppm		61	11
Sulfates ppm		28.6	7
Phosphates ppm		35.5	5.6
Others			

TABLE VIII

SEWAGE POND RESEARCH PROJECT

Location: LACOMBE Sampling Point: 40 ft. from south edge of lagoon about 1/3 from east side. Final Effluent

Date		1958 June 6	July 17	July 24	July 31	Aug. 7	Sept. 10	Sept. 16	Oct. 14	Nov. 14	Nov. 25
Time		11:45am	12:15pm	11:30am	11:30am	11:30am	11:15am	10:30a m	11:45am		11:45am
Weather		Sunny & Warm	Sunny Warm & Windy	Clear & Warm	Sunny & Windy	Sunny & Calm	Sunny & Warm	Sunny Cool & Windy	Sunny & Cool		Cloudy & Sunny
D.O. ppm		33	25.6		18.3	12.0	4.7	3.4	9.6	0.1	0.0
Temperature °C		22	22	22	22	21.5	15.5	11.5	4.5	2.5	1
pH			10.1	10.0	9.8	9.6	9.1	8.9	8.4	8.3	8.27
Odor, T.O.N.										100 slough	450 slough
Alkalinity, ppm	pp		210	201	159	153	67	43	3	0	0
ppm	MO		570	552	591	569	669	672	672	686	753
B.O.D.	Filtered		13.5	8.0	19.9	43.7	35.5	24	31.9	12.4	44.3
ppm	Unfiltered	50	61.2	31	96.3	116	65.2	42.4	65.8	32.4	117
Nitrogens	Total	9	5.6				10.9	12.2	15.4		27.1
ppm	Organic										
	Ammonia				1.7	2.7	3.4	4.7	9.9		20.8
	Nitrite		0.266	0.165	0.2	0.241		0.112			
	Nitrate					Trace	0.1	0.12			
Total	Total	937	1271	1085	1346	1216	1254	1245	1195	1134	1250
Solids	Volatile	222	414	298	435	331	313	321	283	222	302
ppm	Fixed	715	857	787	905	885	941	924	915	912	948
Suspended	Total	86	418	186	372	144	194	151	168	140	92
Solids	Volatile	80	264	158	222	92	148	103	124	136	86
ppm	Fixed	6	154	28	150	52	46	48	44	4	6
Chlorides	ppm						68	69	71	73	75
Sulfates	ppm									39	42
Phosphates	ppm										
Others											
Ice										1"	7"

TABLE VIII

SEWAGE POND RESEARCH PROJECT

Location: LACOMBE Sampling Point: 40 ft. from south edge of lagoon about 1/3 from east edge

Date		1958 Dec. 9	Dec. 30	1959 Jan. 14	Feb. 17	Mar. 24	June 3	July 8	Sept. 1	1960 Jan. 14
Time		11:45am	3:15 pm	12:40pm	12:15 pm	12:00 pm	12:00 N	1:00 pm	4:15 pm	12:15 pm
Weather		Sunny & Cold	Sunny & Cold	Sunny & Cold	Sunny & Cold	Sunny & Warm	Cloudy & Cool	Warm & Windy	Sunny & Windy	Sunny & Calm
D.O. ppm		0	0	0	0	0	20.4		15.3	0
Temperature °C		1	0.5		0.25	2.5	16	14.1	15.5	0.5
pH		7.7	7.55	7.7	7.4	7.3	8.8	9.4	8.7	7.5
Odor, T.O.N.		500 Sewage	750 Sewage	2,500 Sewage	2,500 Sewage	2,500 Sewage	10 sewage	8 sewage	10 sewage	
Alkalinity	pp	0	0	0	0	0	68	107	45	0
ppm	MO	923	945	1340	1065	770	752	498	675	915
B.O.D.	Filtered	157	124				193		6.5	
ppm	Unfiltered	264	197	281	267	155	43.5	31.1	18.9	172
Nitrogens	Total	56.0	52.6	82.9		63	28.8	9.2	7.3	
ppm	Organic						2	4.2	0.6	
	Ammonia	55.7	50	53.5	77.7	64	22.4	2.5	2.1	
	Nitrite						0.033	0.25	0.12	
	Nitrate							0.45	0.21	
Total	Total	1369	1349	1585	1319	955	1082	1024	1028	1231
Solids	Volatile	362	288	366	339	228	266	235	211	301
ppm	Fixed	1007	1061	1219	980	727	816	789	817	930
Suspended	Total	130	76	128	64	62	184	155	78	36
Solids	Volatile	112	72	107	64	54	164	86	74	34
ppm	Fixed	18	4	21	0	8	20	69	4	2
Chlorides ppm		90	88	104	82.5	58	62	65	70	
Sulfates ppm		43	60	37.6	36.7	41	52	48	58	
Phosphates		48.3	45.3	61.3	44.5	42	32	29	27	
Others Oils & Grease mg/l					47.8					
Ice		15"	18"	18"	15"	Open	Open	Open	Open	15"
Liquid					15"	Water	Water	Water	Water	9"
Overflow		No	No	No	No	Yes	Yes	Yes	Yes	No

M Y R N A M

The Myrnam sewage pond system treats a raw domestic sewage from a served population of 420 people. It also serves a school of which 350 students are from out of town. The usual number of business places are connected with no unusual commercial industries present.

		Raw Sewage	Pond No. 1	Pond No. 2
B.O.D., ppm		236	164	151
pH		8.35	7.7	7.65
Alkalinity, ppm	P.P. = 5, M.O. = 665		673	795
Millivolts		-90	-53	-49
Odor, T.O.N.		500 sewage	1000 sewage	1000 sewage
Total Solids, ppm	Total	1725	1486	1430
	Volatile	399	313	313
	Fixed	1326	1173	1117
Suspended Solids, ppm	Total	193	91	54
	Volatile	154	78	53
	Fixed	39	13	1
Dissolved Oxygen, ppm		-	0	0
Temperature, °C		-	3	1

Single samples from the ponds at Myrnam were obtained on January 20th, 1960, and a raw sewage composite sample was collected during the 24 hour period of January 19th and 20th, 1960. Measurements of the sewage flow were taken throughout this 24 hour period with a V-notch weir.

The sewage disposal system consists of two ponds in series with detention times of 11.7 and 24.2 days for ponds #1 and 2 respectively. This gives a B.O.D. reduction of 30.5% for pond #1 and 5.5% for pond #2 and an overall total of 36% reduction. Pond #1 reduction and results from other

places show that a detention time of lower than 24 days is far more efficient.

As can be seen on the summary page, there is a definite difference between the water consumption and the calculated average sewage flow. This could be counted for by infiltration, which is probably because of the high water table in this area.

Analysis in ppm of Myrnam town water supply from wells. Sample taken July 24th, 1957.

Total Solids	600
Ignition Loss	182
Hardness	340
Sulphates	59
Chlorides	10
Alkalinity	440
Nature of Alkalinity	Bicarbonate of soda
Nitrites	Trace
Nitrates	Trace
Iron	2 Plus

MYRNAM

POPULATION - 440 Serving Approximately - 420

Water Consumption - 8,040 gals./day
Sewage Flow - 11,500 gals./day
Number of Connections - 120

SIZE OF PONDS:

Dimensions - Pond #1 - 60' by 60'
- Pond #2 - 103' by 103'

Area - Pond #1 - 0.0825 acres
- Pond #2 - 0.243 acres

Capacity - Pond #1 @ 6 ft. depth - 0.1346 million gals.
- Pond #2 @ 4 ft. depth - 0.2786 million gals.

Detention Time - Pond #1 - 11.7 days
- Pond #2 - 24.2 days

LOADING:

Pond #1 - 329 lbs. B.O.D./acre/day or
54.9 lbs. B.O.D./acre-ft./day
Pond #2 - 77.7 lbs. B.O.D./acre/day or
19.4 lbs. B.O.D./acre-ft./day
B.O.D.Contribution per Capita - 0.0645
Sewage Flow per Capita - 27.4 gals./day

STONY PLAIN

The Stony Plain sewage pond system, which consists of three short detention and one long detention ponds in series receives a raw domestic sewage from a served population of 1040 people. It also serves a school with an enrollment of 866 students, of which approximately one half are from the country. There are the usual number of business places with no unusual industries which might overload the system. The sizes of the lagoons are 0.0517, 0.0517, 0.145 and 9 acres for ponds #1, 2, 3 and 4, and the calculated detention times are 0.93, 0.93, 2.6 and 187 days respectively.

Studies on this system were mostly on pond #3 and began on August 13th, 1958 and terminated on December 9th, 1959. Composite raw sewage samples were collected during 24 hour periods on August 20th and 21st, 1958, and August 24th and 25th, 1959. The sewage flow was measured by the salt dilution method during the second 24 hour period of sampling.

Excluding the B.O.D. of 265 ppm on August 13th, 1958, the average B.O.D. of the effluent from pond #3 was 104 ppm, with only small deviations throughout the summer and winter. This gave a B.O.D. removal of 69% which is superior to conventional primary sewage treatment. Until 1959 only the three pond system had been used and since then a fourth pond, which was completed in 1959, has been added for storage and further treatment purposes. As sampling on pond #4 was not continued in the late winter of 1960, figures are not available for winter treatment, but the two samples obtained in the summer and early winter of 1959 gave an average gave an average B.O.D. of 7 ppm which was a removal of 98%.

B.O.D. REMOVAL SUMMARY

	Influent B.O.D.	Effluent B.O.D.	% Removal
Pond #1	335 ppm (Raw Sewage)	223	33.4
Pond #2	223	-	
Pond #3	-	104	53.4
Pond #4	104	7	93.3

Total --- Ponds 1 to 3 - 69%

Total --- Ponds 1 to 4 - 98%

At no time of the year and even at the time of ice break-up in the spring has there been odors present in the general area of the first three ponds.

All other analysis carried out on the samples showed the same level of concentrations in the summer as in the winter for pond #3, while pond #4 showed increases in pH, dissolved oxygen, total solids and sulfates. At the same time decreases were recorded in odor, alkalinity, total and ammonia nitrogens, phosphates and suspended solids.

The ponds are operated so that the first three are overflowing continuously and the 4th to be drawn down twice a year. With the excellent removal of B.O.D. and little odor in the 4th pond, the draw down liquid should not create any problem along the drainage course which it follows.

Water analysis in ppm of the treated Stony Plain surface water supply taken on November 5th, 1957.

Total Solids	676
Ignition Loss	186
Hardness	475
Sulphates	169
Chlorides	3
Alkalinity	330
Nature of Alkalinity	Bi carbonate of lime and magnesium
Nitrites	Nil
Nitrates	Nil
Iron	Nil

STONY PLAIN

POPULATION - 1300 Serving Approximately - 1040

Water Consumption -71,400 gals./day
Sewage Flow -75,9000 gals./day
Number of Connections -300

SIZE OF PONDS:

Dimensions - Ponds #1 & 2 - 48' by 47'
- Pond #3 - 135' by 47'

Area - Ponds # 1 & 2 -0.0517 acres
- Pond # 3 -0.145 acres
- Pond # 4 -9 acres

Capacity - Ponds #1, #2 & #3 @ 6ft. depth and #4 @ 4ft.depth
- Pond #1 & #2 -0.0703 million gals.
- Pond #3 -0.1976 million gals.
- Pond #4 -14.19 million gals.

Detention Time - Ponds #1 & #2 - 0.93 days
- Pond #3 - 2.6 days
- Pond #4 - 187 days

LOADING:

Pond # 1 - 4920 lbs. B.O.D./acre/day or
984 lbs. B.O.D./acre-ft./day
Pond # 2 - 3400 lbs. B.O.D./acre/day or
680 lbs. B.O.D./acre-ft./day
Pond # 3 - No. samples of effluent of Pond #2
Pond # 4 - 8.8 lbs. B.O.D./acre/day
B.O.D. Contribution per Capita - 0.845 lbs./day
Sewage Flow per Capita - 73.0 gals./day

SKETCH OF STONY PLAIN SEWAGE PONDS

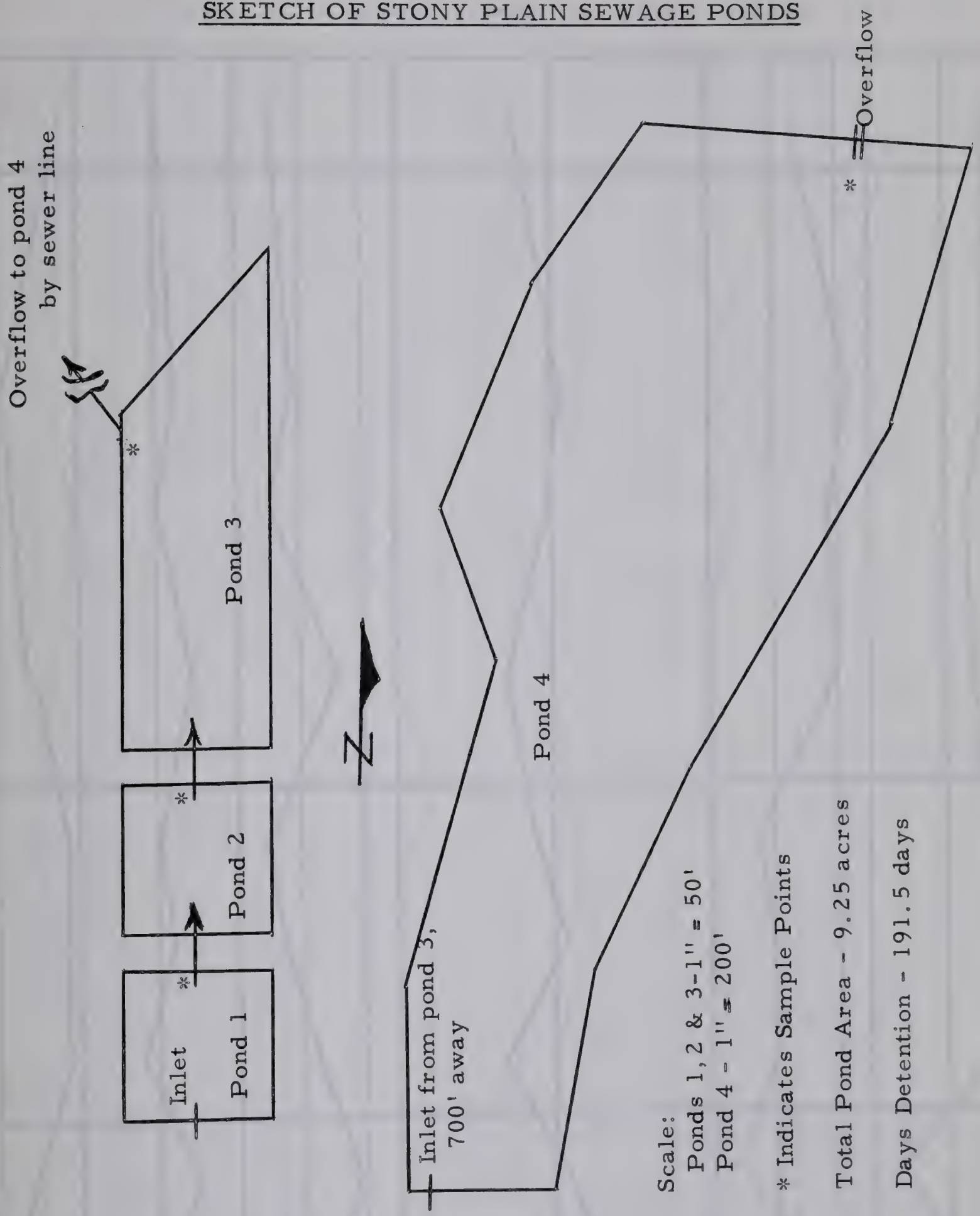
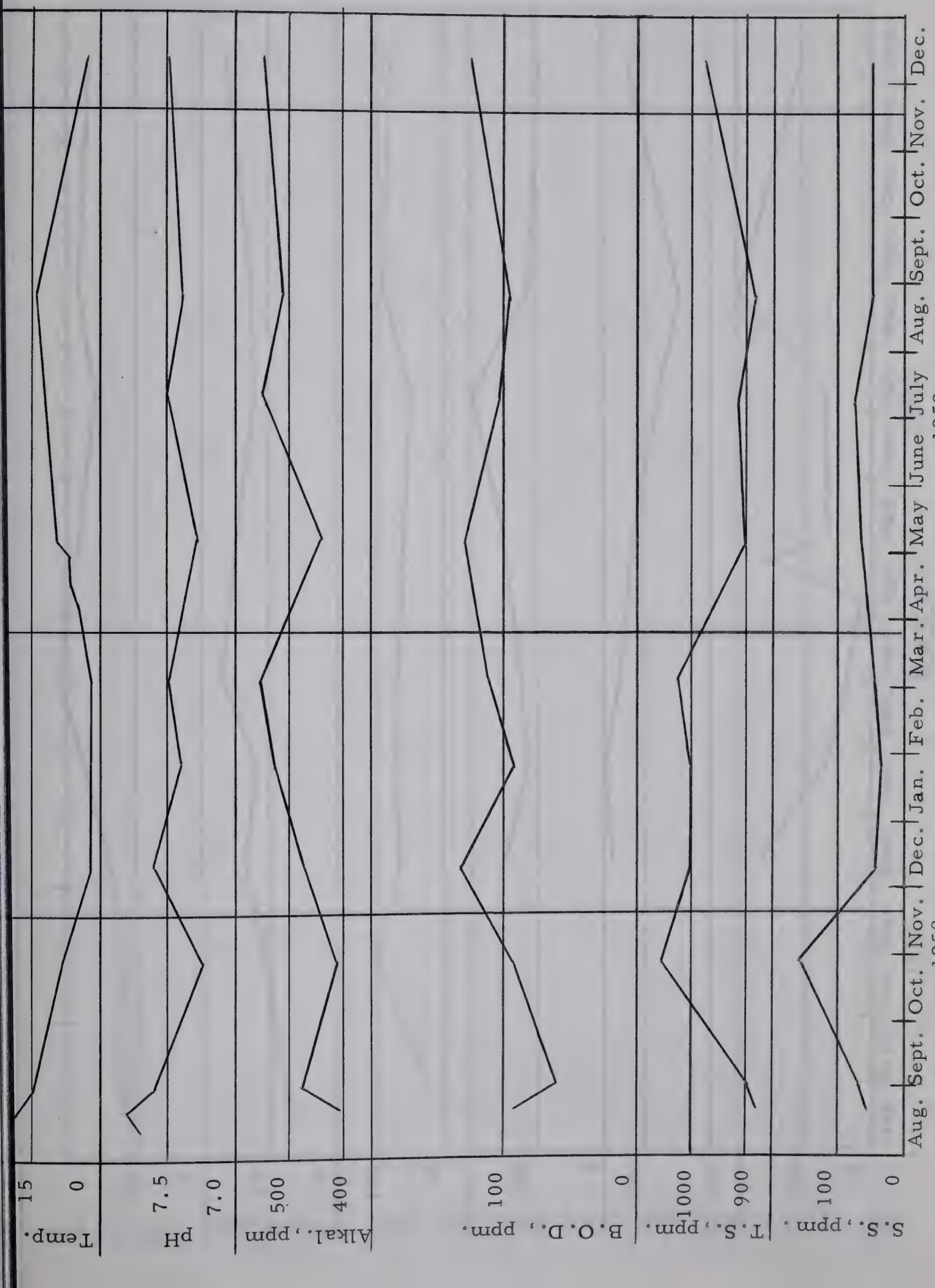


Figure XI

Figure XII


Temp.
15
0
pH
7.5
7.0
Alkal., ppm
500
400
B.O.D., ppm.
100
0
T.S., ppm.
1000
900
S.S., ppm.
100
0
Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1958
1959
DATE
STONY PLAIN #3 SEWAGE POND TRENDS

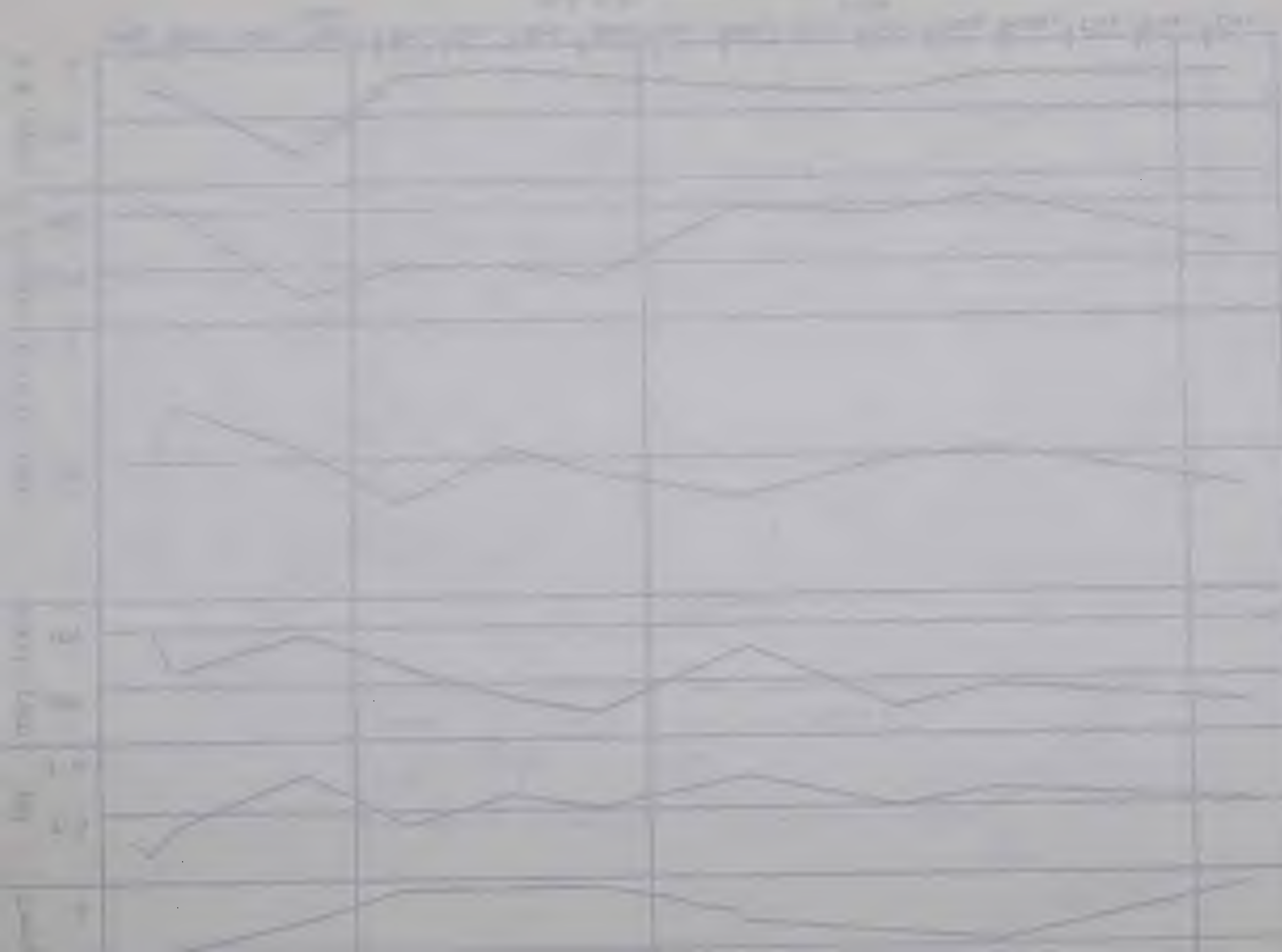
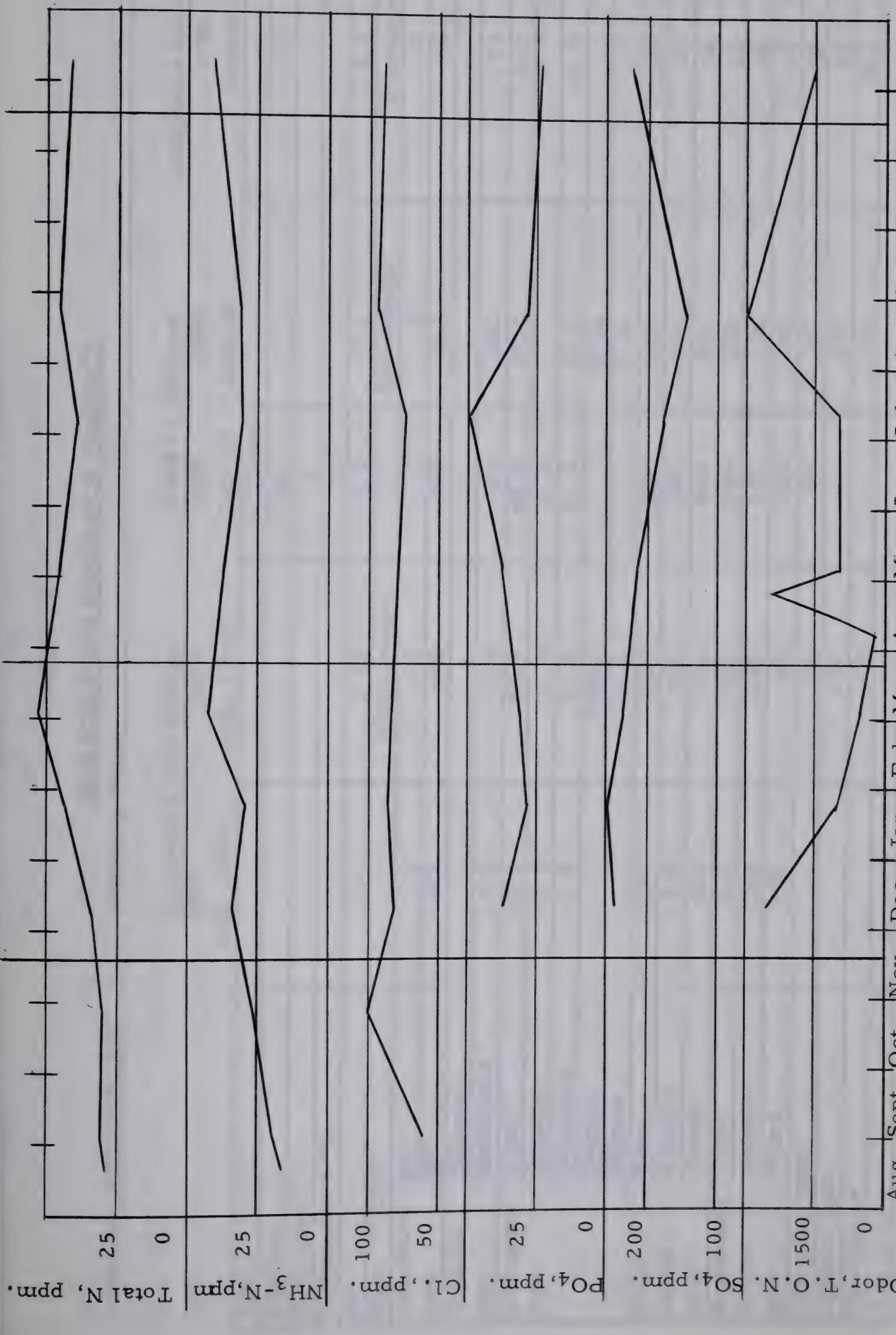


Figure XII



STONY PLAIN #3 SEWAGE POND TRENDS

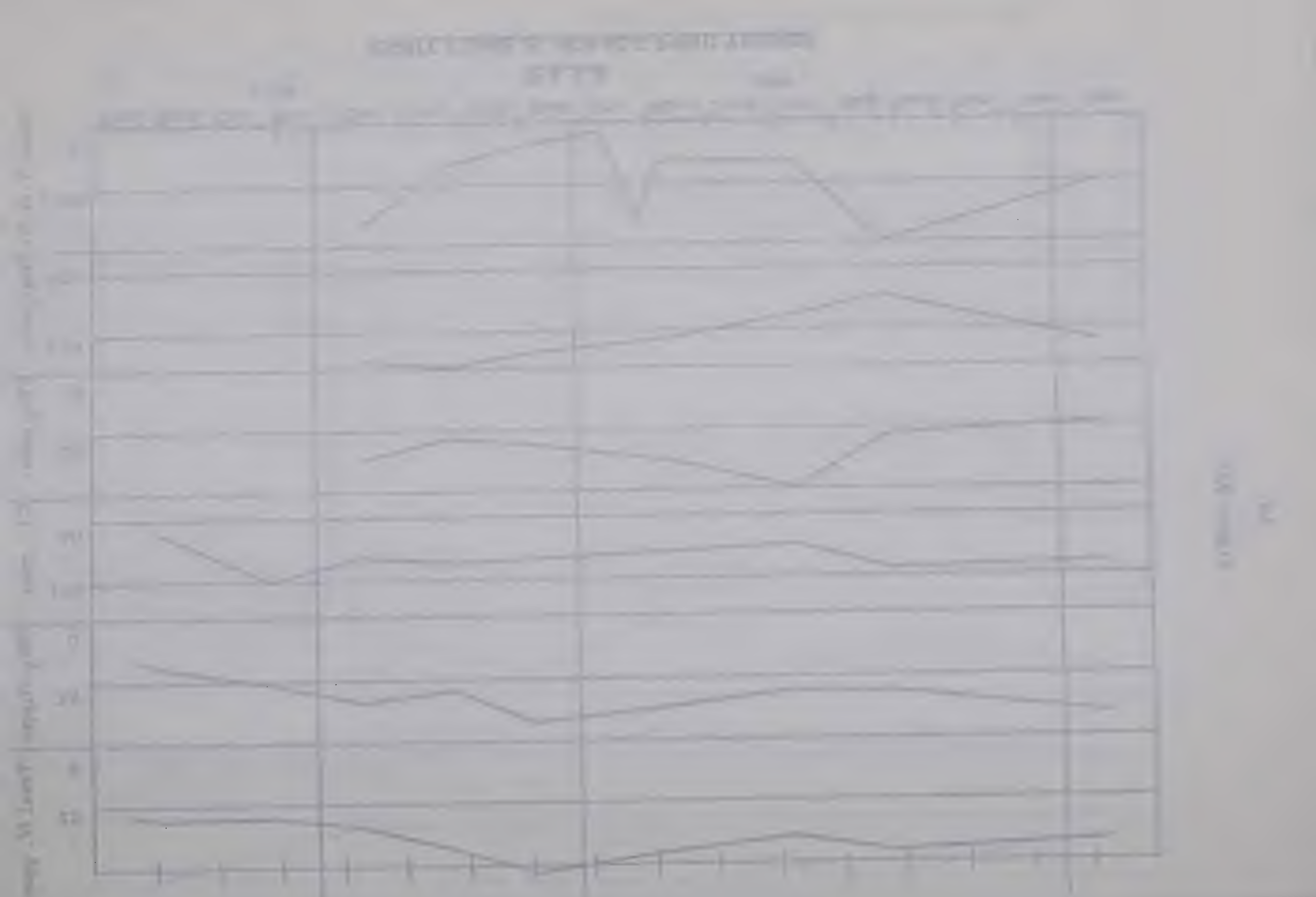


TABLE IX

SEWAGE POND RESEARCH PROJECT

Location: STONY PLAIN Sampling Point

Date		Composite Raw Sewage 1958 Aug. 20-21	Composite Raw Sewage 1959 Aug. 24-25	Pond #1 Effluent 1958 Oct. 27	Pond #1 Effluent 1959 July 10	Composite Ice Samples 1959 March 3
Time				2:30 pm		
Weather				Sunny		
D.O. ppm				0		
Temperature °C				9		
pH		7.2	7.15	7.6	7.1	8.7
Odor, T.O.N.			2000 sewage		500 sewage	8 sewage
Alkalinity	pp	0	0	0	0	2
ppm	MO	322	460	446	463	56
B.O.D.	Filtered					
ppm	Unfiltered	376	294	263	182	24
Nitrogens	Total	30.5	42.4	40.6	37.2	9.2
ppm	Organic	13.5	3.4	8.3		
	Ammonia	17.0	31.0	32.3	33.0	2.7
	Nitrite		0.002		0.04	
	Nitrate		1.5		0.15	
Total	Total	1197	1209	1222	1005	144
Solids	Volatile	535	455	357	413	60
ppm	Fixed	662	754	865	592	84
Suspended	Total	336	322	236	216	28
Solids	Volatile	244	260	132	116	16
ppm	Fixed	92	62	104	100	12
Chlorides ppm			74	85	92	12
Sulfates ppm			220		230	24
Phosphates			28		25	4.3
Others						

TABLE IX

SEWAGE POND RESEARCH PROJECT

Location: Stony Plain Sampling Point: Final Effluent Outfall (Pond #3)

Date		1958 Aug. 13	Aug. 20-21	Sept. 2	Sept. 30	Oct. 27	1959 Dec. 10	Jan. 28	Mar. 3	May 5	July 10
Time		3:15 pm	24 hr. sample	10:30am	Not in Working Order	2:30pm			10:45am	4:30pm	
Weather		Sunny & Calm		Cloudy		Sunny			Sunny	Sunny	
D.O. ppm		10.5	0	0		0	0	0	0	0	
Temperature °C		21.5		14.5		8.5	2	2°C	2	9	
pH		7.7	7.8	7.6		7.25	7.6	7.4	7.5	7.3	7.5
Odor, T.O.N.							2500 Sewage	1000 Sewage	500 Sewage	1000 Sewage	1000 Sewage
Alkalinity ppm	pp	0	0	0		0	0	0	0	0	0
	MO	351	405	479		418	474	530	560	446	552
B.O.D. ppm	Filtered	92.3	42.7	37.8		36.8					
	Unfiltered	265	93.9	61.6		93.8	133	91.9	112	130	103
Nitrogens ppm	Total	17.6	28.6	31.1		30.0	34.0	44.2	52.9	45.4	39.5
	Organic										
	Ammonia	10.7	16.3	19.4		26.8	33.6	29.8	42.6	37.8	31
	Nitrite	0	0	0						0.086	.02
	Nitrate	0	0	0							.15
Total Solids ppm	Total	919	877	899		1058	1007	1004	1026	903	917
	Volatile	351	275	292		351	275	279	286	274	274
	Fixed	568	602	602		707	732	725	740	629	643
Suspended Solids ppm	Total	134	59	70		158	46	40	46	64	78
	Volatile	130	53	59		136	31	40	38	52	40
	Fixed	4	6	11		22	15	0	8	12	38
Chlorides ppm				61		101	81.5	88	84		74
Sulfates ppm							245	255	238	218	179
Phosphates ppm							36.7	28.9	31.5	37.7	50
Others Oils & Greases mg/l		Pond by passed		Not in good working order By pass	By pass			28.9			
Ice							8"	1'	8"		
Overflow							Yes	Yes	Yes		

SEWAGE POND RESEARCH PROJECT

Location: STONY PLAIN Sampling Point: Final Effluent Outfall (Pond #3 & #4)

		Pond No. 3 1959		Pond No. 4 1959	
Date		Aug. 24	Dec. 9	Aug. 24 & 25	Dec. 9
		Composite Sample		Composite Sample	
Time			3:45 pm		3:30 pm
Weather			Sunny & Cold		Sunny & Cold
D.O. ppm		0	0	Varied 7.9 to 10.0	6.3
Temperature oC		Varied 12 to 14.5	3	Varied 15 to 17.5	1
pH		7.4	7.5	8.4	7.75
Odor, T.O.N.		3000 sewage	1500 sewage	8 musty	12 musty
Alkalinity pp			0	15	0
ppm	MO	515	550	350	490
B.O.D.	Filtered	70.5			
ppm	Unfiltered	97.5	125	3	11
Nitrogens	Total	45.8	42.0	5.5	5.6
ppm	Organic		0.6		1.4
	Ammonia	32	41.5	4.0	3.9
	Nitrite	.003	Trace	0.017	0.1
	Nitrate	1.0	0.05	0.65	1.76
Total	Total	885	975	1113	1380
Solids	Volatile	271	277	286	336
ppm	Fixed	614	698	827	1044
Suspended	Total	68	50	10	7
Solids	Volatile	46	43	8	7
ppm	Fixed	22	7	2	0
Chlorides ppm		94	90	85	124
Sulfates ppm		144	224	387	409
Phosphates ppm		29	24	7	5
Others			Detergents 18		Detergents 8
Ice					12"
Liquid					54"

THORSBY

This single short detention pond of 10.35 days detention receives a raw sewage from a population of approximately 360 people and also serves a school of 423 students, of which 257 are country students. It also serves a cheese factory which produces approximately 650 lbs./day of cheese. The cheese whey is used by the surrounding farmers and the only sewer drainage occurs from the washing of the cheese and vats.

		Raw Sewage	Pond Samples	
			Dec.31/59	Jan.6/60
B.O.D. ppm		1125	> 646	653
ph		7.4	6.4	6.5
Alkalinity, ppm		468	445	485
Millivolts		-35	+20	+18
Odor, T.O.N.		-	-	-
Total Solids ppm	Total	1989	1849	1319
	Volatile	1278	1191	612
	Fixed	711	658	707
Suspended Solids ppm	Total	324	318	222
	Volatile	296	296	188
	Fixed	28	22	34
Dissolved Oxygen, ppm		-	0	0
Temperature ^{o}C		-	3.5	3

A composite raw sewage sample was collected during the 24 hour period of December 30th and 31st, 1959 and measurements of the sewage flow were made throughout this period of time. Samples of the pond were also taken on December 31/59 and January 6/60. A B.O.D. reduction of approximately 42.2% was obtained across this short detention pond, again showing high efficiency in sewage disposal by the short detention or anaerobic ponds.

Analysis in ppm of treated surface water for the Village of Thorsby.

	Winter January 15, 1958	Summer September 9, 1959
Total Solids	534	312
Ignition Loss	170	144
Hardness	335	175
Sulphates	69	3
Chlorides	10	Nil
Alkalinity	370	235
Nature of Alkalinity	Bicarbonate of soda, lime and magnesium for both.	
Nitrites	Nil	Nil
Nitrates	Nil	Nil
Iron	0.2	1.0

THORSBY

POPULATION - 491 Serving Approximately - 360

Water Consumption - 15,000 gals./day
Sewage Flow - 14,400 gals./day
Number of Connections - 90

SIZE OF POND:

Dimensions - 65' by 46'
Area - 0.0686 acres
Capacity @ 8 ft. depth - 0.149 million gals.
Detention Time - 10.35 days

LOADING:

2,360 lbs. B.O.D./acre/day or
295 lbs. B.O.D./acre-ft./day
B.O.D. Contribution per Capita - 0.45 lbs./day
Sewage Flow per Capita - 66.2 gals./day

T W O H I L L S

The sewage pond system of Two Hills receives a raw domestic sewage from a population of approximately 800 people. It also serves a school population of approximately 850, of which about 700 students are from outside of town. There are no major commercial industries aside from the usual garages and cafes in town.

		Raw Sewage	Pond No. 1	Pond No. 2
B.O.D. ppm		294	248	195
pH		8.2	7.8	7.7
Alkalinity, ppm		890	900	905
Millivolts		-80	-57	-53
Odor, T.O.N.		500 sewage	1000 sewage	1500 sewage
Total Solids ppm	Total	1557	1456	1415
	Volatile	371	287	246
	Fixed	1186	1169	1169
Suspended Solids ppm	Total	214	142	92
	Volatile	190	126	92
	Fixed	24	16	0
Dissolved Oxygen, ppm		-	0	0
Temperature, ^{o}C		-	2	1.5

A composite raw sewage sample was collected at the town of Two Hills during a 24 hour period of January 25th and 26th, 1960, and single grab samples from the two ponds were taken on January 26th, 1960. Sewage flow measurements were made throughout the 24 hour period with a V-notch weir.

The system consists of two short detention ponds in series with detention times of 1.9 and 1.05 days for ponds #1 and 2 respectively. This system is quite unique when compared to other systems because of the depths

involved. Pond #1 has a depth of 18 feet and pond #2 a depth of 10 feet, whereas the depths of other systems studied are on the average of 5 or 6 feet.

The first pond gives a B.O.D. reduction of 15.65% and the second pond an additional 18% for a total of 33.65%. These reductions are somewhat lower than those obtained for other ponds of shallower depths.

There is quite a difference between the water consumption and calculated sewage flow and this difference may be accounted for by infiltration which is quite possible because of the high water table present here.

TWO HILLS

POPULATION - 886 Serving Approximately - 800

Water Consumption - 26,810 gals./day
Sewage Flow - 53,000 gals./day
Number of Connections - 200

SIZE OF PONDS:

Dimensions - Ponds #1 & #2 - 40' by 40'

Area - Ponds #1 & #2 - 0.0367 acres

Capacity - Pond #1 @ 18 ft. depth - 0.1009 million gals.
- Pond #2 @ 10 ft. depth - 0.053 million gals.

Detention Time - Pond #1 - 1.9 days
- Pond #2 - 1.05 days

LOADING:

Pond #1 - 3870 lbs. B.O.D./acre/day or
215 lbs. B.O.D./acre-ft./day
Pond #2 - 3580 lbs. B.O.D./acre/day or
358 lbs. B.O.D./acre-ft./day
B.O.D. Contribution per Capita - 0.195 lbs./day
Sewage Flow per Capita - 66.2 gals./day

SEWAGE PONDS IN THE PEACE RIVER AREA

Town	Population	Size of Ponds (acres)	Detention Time (days)
Berwyn	371	#1 - 2.8	150
		#2 - 1.3	95
		Total 4.1	245
Donnelly	287	3.4	290
Fahler	802	7.2	310
*Fairview	1448	20	105
Girouxville	314	3.4	365
Grande Prairie	7410	51.7	115
Grimshaw	1051	8.3	175
Rycroft	305	4.1	450
Sexsmith	345	6.9	520
Spirit River	834	#1 - 0.165	11
		#2 - 2.4	100
		#3 - 2.4	100
		Total - 4.965	211

* Fairview system consists of three long detention ponds but individual sizes are unknown.

The detention times were calculated by considering a sewage flow of approximately 40 gals./capita/day as there were no flow measurements taken. Since there is no underground water in most of this area, the above figure of sewage flow would be approximately equal to the water consumption.

Single samples of the sewage ponds from 10 different towns in the Peace River area were obtained in June, 1959. As there were no composite raw sewage samples collected an overall true evaluation of the ponds cannot

be made.

The B.O.D.'s obtained, which in most cases were low, indicated that a good treatment was present. Percent B.O.D. removals shown on the data sheets were calculated with caution as the raw sewage B.O.D.'s were not available. As the main summary report indicates, an average raw sewage B.O.D. of 325 ppm was obtained for several small towns in central Alberta and this figure was chosen as the "approximate" influent B.O.D. with a slightly higher figure of 350 ppm for Grande Prairie because of the larger size.

In most cases, high dissolved oxygen and pH's, and low alkalinities and ammonia nitrogens were recorded. There were no odors or very slight in the general areas for all the ponds except where a very strong odor from the Spirit River #1 pond was noticed.

Although only single samples were obtained from the ponds, a general conclusion can be drawn that they operate very satisfactorily in the summers. This conclusion does not cover the ice cover periods and the spring turnovers which are the most critical times of all.

TABLE X

SEWAGE POND RESEARCH PROJECT

Location: PEACE RIVER AREA Sampling Point: As directed

		Grande Prairie	Sexsmith	Rycroft		Spirit River	
				Pond #1	Pond #2	Pond #1	Pond #2
Date		June 15	June 15	June 15		June 15	
Time		10:00 a.m.	12:15 p.m.	2:30 p.m.	2:15 p.m.	4:15 p.m.	4:15 p.m.
Weather							
D.O. ppm		11.4	20.8	14.3	13.5	0	15.8
Temperature °C		11	16	19	18	15	15.5
pH		10.3	9.1	9.0	9.8	7.4	9.9
Odor, T.O.N.							
Alkalinity pp		117	261	51	69	0	105
ppm	MO	162	1026	183	165	678	237
B.O.D.	Filtered						
ppm	Unfiltered	85	107	71	73	211	56
Nitrogens	Total						
ppm	Organic						
	Ammonia	23	2.6	4.2	0.2	35	6.8
	Nitrite						
	Nitrate						
Total	Total	787	1669	675	1105		1476
Solids	Volatile	414	422	259	487		353
ppm	Fixed	373	1247	416	618		1123
Suspended	Total	336	260	142	186	94	140
Solids	Volatile	268	132	114	146	90	94
ppm	Fixed	68	128	28	40	4	46
Total % B.O.D. Removal				77.5		82.7	
Others: % B.O.D. Removal per pond		75.8	66.0	78.1	2.8	35.1	73.4

TABLE X

SEWAGE POND RESEARCH PROJECT

Location: Peace River Area Sampling Point: As directed

		Fairview		Berwyn	Grimshaw	Donnelly	Falher	Girouxville
		Pond #1	Pond #3					
Date		June 16		June 16	June 16	June 17	June 17	June 17
Time		11:30 a.m.	11:30 a.m.	2:00 p.m.	3:30 p.m.	10:30 a.m.	12:00 N	2:00 p.m.
Weather								
D.O. ppm		13.0	15.2	6.4	1.8	0.5	7.1	0.2
Temperature °C		15.5	17	18	18	15.5	19	20
pH		8.4	10.1	7.9	8.5	7.85	9.2	7.8
Odor, T.O.N.								
Alkalinity	pp	6	72	0	15	0	66	0
ppm	MO	372	144	246	243	411	258	444
B.O.D.	Filtered							
ppm	Unfiltered	52	40	24	17	24	19	21
Nitrogens	Total							
ppm	Organic							
	Ammonia	9.0	1.2	9.0	3.7	7.6	2.3	7.8
	Nitrite							
	Nitrate							
Total	Total	1258	778	652	663	2286	1307	1206
Solids	Volatile	518	328	254	228	545	244	340
ppm	Fixed	740	450	398	435	741	1063	866
Suspended	Total	156	102	21	14	32	40	112
Solids	Volatile	112	73	17	9	18	18	20
ppm	Fixed	44	29	4	5	14	22	92
Total % B.O.D. Removal		87.7						
Others: % B.O.D. Removal per pond		84.0	23.1	92.5	94.7	92.5	94.1	93.5

SEWAGE POND LABORATORY RESEARCH PROJECT

INTRODUCTION

In an attempt to investigate the effect of dairy wastes on sewage ponds, a small scale or pilot plant pond was set up under controlled conditions in the laboratory. The apparatus was operated such that:

1. The temperature of the deepfreeze was controlled through the use of a time clock.
2. To simulate daylight for the activity of micro-organisms, 2 - 40 watt fluorescent and 2 - 15 watt incadescent lamps were used.

DESCRIPTION OF APPARATUS

A 17 cubic foot deepfreeze was obtained and several alterations were made for the experimental purposes. These alterations were as follows:

1. A thermostat could not be used for temperature control, therefore a 30 minute cycle timeclock was installed into the circuit and the temperature was obtained by a simple manipulation of the deepfreeze running time and shut-off time.
2. Fluorescent lights had to operate at, or near, room temperature for high efficiency, thus they could not work inside the deep-freeze. This was solved by removing the door of the deep-freeze and placing a plywood sheet on the top, into which a hole was cut out just above a stainless steel tank and the fluorescent lights fixed above this hole. The incandescent lamps were also fixed above the tank. The number of lighting hours were controlled by a 24 hour cycle timeclock.
3. The ponds were simulated by two polythene containers which were placed in a water bath in the tank.

4. A continuously running fan was installed so that it circulated the air around the tank, whereby it prevented the segregation of cold and warm air around this tank.
5. In order that lower temperatures would not be obtained, a heating lamp and thermostat, set up in series, were placed immediately behind the fan which began a circulation of the warm air at once. This safety precaution is most important if a test run is made, at a temperature very near the freezing point of water.

TABLE XI

RESULTS OF THE EXPERIMENTAL RUNS

Composition of Batch Feed in %	No. of Days at Run	Loadings: 20 lbs./acre day			Loadings: 60 lbs./acre/day		
		Average pH	Average Millivolts	B.O.D. ppm	Average pH	Average Millivolts	B.O.D. ppm
Initial Mixed Culture		8.05	-75.0	-	8.05	-75.0	-
100 Sewage	38	8.31	-85.2	-	7.92	-63.7	-
80 Sewage & 20 Milk	14	8.05	-71.1	208	7.59	-44.9	315
60 " & 40 "	8	7.95	-65.3	-	7.56	-44.8	-
20 " & 80 "	10	7.92	-65.3	110	7.54	-44.2	345
80 Sewage & 20 Buttermilk	10	7.99	-70.2	114	7.63	-50.1	210
40 " & 60 "	7	7.91	-64.0	64	7.57	-45.7	141
20 " & 80 "	7	7.88	-62.6	116	7.53	-42.6	272
80 Sewage & 20 Cheese Wey	7	7.91	-64.1	96	7.60	-47.3	192
50 " & 50 " "	8	7.84	-59.8	-	7.48	-38.3	-
20 " & 80 " "	7	7.68	-48.6	127	7.28	-23.7	224

Operating Temperature 6.9 to 7.8 ^{o}C

TABLE XI

Analysis of the final material at the end of the 20% sewage and 80% cheese whey run.

	20 lbs./acre/day		60 lbs./acre/day	
	Settled	Mixed	Settled	Mixed
pH	7.69	7.60	7.33	7.22
Millivolts	-48	-43	-28	-19
Alkalinity, ppm	360	380	280	305
B.O.D., ppm	45	127	111	224
Ammonia Nitrogen ppm	22.8	22.8	26.5	26.5
Phosphates, ppm	27.0	27.5	26.5	27.0
Odor, T.O.N.	500 sewage	1000 sewage	1000 sewage	3000 sewage
Total Solids, ppm				
Total	653	963	616	972
Volatile	150	377	211	425
Fixed	503	586	405	547
Suspended Solids, ppm				
Total	36	284	110	456
Volatile	36	228	110	324
Fixed	0	56	0	132

The original mixed culture for the simulated ponds was obtained from the Lacombe sewage pond. A daily batch feed was added and an equal volume taken out on which the analysis were run. The sewage portion of the feed was obtained daily at approximately 11:00 a.m. from the raw sewage influent line into the Edmonton #3 sewage treatment plant. The average B.O.D. of this sewage was 325 ppm and this figure was chosen arbitrarily to be the feed B.O.D.

B.O.D.'s were run on milk, buttermilk and cheese whey and the following values were obtained:

1. Milk 120,500 ppm
2. Buttermilk 91,125 ppm
3. Cheese Whey 51,750 ppm

These figures and the raw sewage B.O.D. were used in calculation of the ratio of volumes in order that a feed B.O.D. of 325 ppm was obtained.

The average pH and millivolts were obtained by considering the results over the period of time that the particular run was made. As there was a gradual change in pH and millivolts, this average is more indicative of the results than a report of the daily results or the range of results would be.

The results for both loadings showed generally the same pattern during the loadings of the different dairy wastes at the different compositions of the feed. The pH and millivolts were lower in all cases for the higher percentage of dairy wastes with a slight recovery at the beginning of each new low composition dairy waste.

A good B.O.D. removal was obtained at the 20 lbs./acre/day loading for all three dairy wastes used. The 60 lbs./acre/day loading also had a good removal except for the milk run which had B.O.D.'s quite similar to the feed B.O.D. A dissolved oxygen was not obtained whenever it was tested for in either loading, thus making it an anaerobic system.

These results indicate that dairy wastes can be treated quite successfully in conjunction with sanitary sewage if the B.O.D. load by the dairy wastes is not too high. As no work with heavier B.O.D. loads by dairy wastes were carried out, critical values can not be made for treatment purposes.

SUMMARY OF OBSERVATIONS

ODORS

Odors in the general area and of the liquid in the ponds were at a minimum or completely absent throughout the late Spring, Summer and Fall.

In long detention ponds, the ice cover during the winter increased odors from summer averages of 10 to winter averages of 1500 at Drayton Valley and up to the end of December at Lacombe and Holden. Lacombe showed a subsequent increase to 2500 which remained until break up of the ice while Holden had an increase up to 20,000 at the latter part of the ice cover. All odors were of a sewage type except for the latter part of the winter at Holden where a distinct change to hydrogen sulfide odor was noticed.

Short detention ponds at Daysland and Stony Plain had odors of 10,000 and 1500 respectively and they were about the same strength throughout the year. A slight odor was noticed in the summer at Stony Plain. This odor did not persist at distances greater than 100 feet away. At Daysland a very strong odor was present and again, as at Holden, it was a distinct hydrogen sulfide odor.

The hydrogen sulfide odor resulting at Holden and Daysland is most likely coming from the reduction of sulfates to sulfides. High concentration of sulfate (approximately 500 to 1,000 ppm) is associated with this factor of pond operation.

Odors were obtained throughout the Summer and Fall at the Bruderheim pond as it never recovered fully. Odors between 500 and 1,000 were obtained throughout the Summer and a strong dairy plant waste

odor was noticed in the air for some distance away from the pond. The Winter odors reached a maximum of 15,000 of a dairy plant waste type.

Observations of the Spring transition period were made in the Spring of 1959. The observations, at approximately weekly intervals, were made of the odor of the liquid and odor in the air around the ponds.

The periods of time stated below indicate the recovery time from ice break-up to the time when no odor in the air was noticed. The short detention ponds are not listed as these have only a slight odor present in the general area throughout the year.

TABLE XII

LOCATION	RECOVERY TIME IN WEEKS
DRAYTON VALLEY	
Pond #1	3
Pond #3	1
BRUDERHEIM	No recovery
HOLDEN	8
LACOMBE	4

From the Drayton Valley system it can be seen that the final (#3) pond had a shorter recovery time than that of the first pond and also that of the single cell system at Lacombe. This can be attributed to the absence of sludge which is present only in the first cell and also in the single cell system.

B.O.D. LOADINGS & REMOVALS

TABLE XIII

A - SHORT DETENTION PONDS

	Detention Time Days	Influent or Raw Sewage B.O.D. ppm	% B.O.D. Removal	LOADINGS lbs.acre/day	lbs./acre ft./day
DAYSLAND	6.2	702	47.8	2,620	455
STONY PLAIN					
Pond #1	0.93	335	33.4	4,920	984
Pond #2	0.93	223	32.2	3,400	680
Pond #3	2.6	150	30.7	2,380	476
CALMAR	4.65	615	54.3	1,390	348
THORSBY	10.35	1,125	42.2	2,360	295
MYRNAM					
Pond #1	11.7	236	30.5	329	54.9
Pond #2	24.2	164	8.0	77.7	19.4
TWO HILLS					
Pond #1	1.9	294	15.7	3,870	215
Pond #2	1.05	248	21.4	3,580	358

TABLE XIII

B LONG DETENTION PONDS

	Detention Time Days	Influent or Raw Sewage B.O.D. ppm	% B.O.D. Removal	LOADINGS lbs./acre/day
BRUDERHEIM	200	-	-	-
HOLDEN	275	485	82.7 (summer) 72.5 (winter)	19.2
LACOMBE	205	338	82.5 (summer) 38.5 (winter)	24.4
STONY PLAIN #4	187	104	93.3 (summer)	8.8
CALMAR	60	172	38.8 (winter)	89
DRAYTON VALLEY				
Pond #1	52	302	73.3 (summer) 56.3 (winter)	79.4
Pond #2	33	80 (summer) 132 (winter)	68.8 (summer)	33 (summer) 55 (winter)
Pond #3	36	-	19.0 (winter)	-

Excluding the loadings at Myrnam, the short detention ponds received and treated quite successfully loadings ranging from 1390 lbs/acre/day (Calmar) to 4,920 lbs/acre/day (Stony Plain).

Some odor problems were encountered in short detention ponds where a high sulfate content was present or the pond received dairy plant wastes but these did not effect the treatment efficiencies to any extent. The Summer and Winter operations proved to be the same in B.O.D. removal.

The long detention ponds received loadings ranging from 8.8 lbs/acre/day (Stony Plain Pond #4) to 79.4 lbs/acre/day (Drayton Valley Pond #1). In the Summer all efficiencies were quite good, while Winter efficiencies were in a lower range for the late Winter when the most critical conditions were obtained.

With the results shown on the preceding table it can be seen that a combination of the short and long detention systems would give very good treatment of sewage from the point of view of B.O.D. removal, nitrogen and phosphate decomposition and lowering of the detergents and oils and greases content.

DISSOLVED OXYGEN

There was a large variation of dissolved oxygen found in all seasons of the year. The D.O. was found in all long detention ponds with the exception of Bruderheim which never fully recovered in the Spring and Summer. No D.O. was detected in the short detention ponds (Stony Plain and Daysland) in any of the seasons.

The summer D.O. showed the greatest variation between 1.9 (Holden) and 33.0 ppm (Lacombe) while the Fall variations were from 0.1 (Lacombe) to 12.2 ppm (Holden). Some D.O. was detected under the ice during the first part of the winter (9.7 ppm maximum at Holden) but this quickly disappeared as a thicker ice layer and a snow cover was obtained.

In the Spring D.O.'s were not obtained until the ponds recovered which made it late Spring or early Summer because of the longer winter periods obtained in Alberta.

On June 24 and 25, 1958 the dissolved oxygen was run on the Holden sewage pond at intervals of three hours during the 24 hour period. The results, tabulated below, showed that immediately after sundown, D.O.'s began to decrease until the morning, when once again sunlight was obtained.

TABLE XIV

TIME	SURFACE D.O. ppm	2 Ft. Depth D.O., ppm
12:00 Noon	15.6	10.3
3:00 p.m.	15.6	12.0
6:00 p.m.	15.6	15.1
9:00 p.m.	13.2	12.2
12:00 Midnight	7.1	6.5
3:00 a.m.	4.5	4.0
6:00 a.m.	4.2	3.3
9:00 a.m.	7.8	7.0

At the time of sampling the overall depth of the pond was 3 feet and sampling was done from a raft. The deeper sample was taken approximately one foot off the bottom of the pond.

pH

Long detention ponds showed a general cycle of pH throughout the year. The pH obtained in the late Spring, Summer and Fall were quite high, in the range of 8.3 to 10.2 and in the Winter they usually dropped to the range of 7.3 to 8.0. The high summer pH was during the periods when a dissolved

oxygen was obtained.

The long detention pond at Bruderheim was not operating in the above fashion. The pH range for the Summer was 7.1 to 7.8 and for the Winter it dropped below 7.0 with a minimum of 5.95 obtained in March, 1959.

Short detention ponds showed the same pH range of between 7.0 to 7.8 in the operation throughout the year.

With the exception of Bruderheim and Thorsby, no other pond obtained a pH below 7.0.

NITROGEN

The total and ammonia nitrogen analysis varied in a similar fashion, with the total nitrogen content being slightly higher than the ammonia nitrogen content.

In short detention ponds, the concentration of the nitrogens stayed at approximately the same level as for the entering raw sewage. Multiple short detention ponds (Stony Plain) showed a slight decrease at the different stages but not enough to conclude that nitrogen compounds were decomposing.

Long detention ponds showed that nitrogen contents decreased to very low concentration in the summer and fall operations. Subsequent ice cover resulted in increasing concentration to that of the raw sewage. With the Spring turnover nitrogen concentrations were found to decrease once again. This occurred in single cell ponds, while multicell ponds showed a gradual decrease of concentration from the first to the last pond in the Summer and in the Winter they were at approximately the same as the raw sewage. The last pond of the multicell system usually had traces of nitrogens,

while single cells had measureable amounts of approximately 1 or 2 ppm in Summer operations.

The nitrite and nitrate nitrogen concentrations were quite low during any season and also in any system with a somewhat lower concentration in the Winter for long detention ponds. The Summer concentrations of the nitrate and nitrite were in the order of 0.1 and 0.002 ppm respectively.

The Stony Plain 4th pond had a nitrate content which was approximately 1 ppm or ten times higher than the average for other ponds. This was the only pond that differed from all of the rest.

PHOSPHATES

The analysis for the ortho-phosphate here showed that a similar behavior of the concentration throughout the year was not obtained for similar ponding systems. At Stony Plain the short detention ponds had a concentration approximately the same as the raw sewage phosphate content, while the Daysland pond showed an increase in concentration of 68%. The Holden and Drayton Valley long detention ponds behaved similarly in that the phosphate concentration in the Summer, with the high pH present was low while Winter concentrations increased to that of the raw sewage content.

A dissimilar behavior of long detention ponds occurred at Lacombe and Bruderheim. At Lacombe the Winter concentration was approximately 33% higher than that of the raw sewage content and only 19.5% lower in the Summer, which is higher than for Holden (76% and Drayton Valley 88%). Although high pH's were obtained at Lacombe in the summer, the phosphate content remained quite high. The Bruderheim long detention pond behaved quite differently than any other pond. The phosphate content in the Winter

reached a maximum of 203 ppm and the Summer average was approximately 100% higher than the 17 ppm phosphate in the raw sewage. The high Winter concentration could possibly be explained by considering the low pH's of below 7.0 obtained during that period.

At present the peculiar behavior of the ortho-phosphate content can not be explained but it is believed that a combination of pH, temperature, hardness, alkalinity and bacterial reaction may have possible effects upon the content at any season. As further investigations were not done on this problem, a definite conclusion cannot be made..

SULFATES

The sulfate content of the ponds were mainly affected by the content in the town water supplies. There was some variation in concentration between different seasons such as a decrease in the Winter at Daysland and Bruderheim and an increase at Holden, Stony Plain and Drayton Valley, while Lacombe showed no variation. This increased concentration in the Winter could mainly be attributed to the freezing of the liquid.

The concentration of sulfate in the liquid varied from 0 (Bruderheim) to 1922 ppm (Holden). Lacombe had the lowest average content at approximately 46 ppm, while Drayton Valley and Stony Plain followed at 240 (Pond 3) and 270 ppm (Pond 3) respectively in the Winter. Daysland at 680 ppm in the Winter and Holden at 1625 ppm also in the Winter followed next. Bruderheim's concentrations dropped from 105 ppm in the late Fall to 0 ppm in the late Winter. This shows that the sulfate was reduced to either the sulfide or some other material which did not show on the analysis. It is possible that some reduction of sulfate to sulfide occurred at Lacombe but this was insufficient to detect any

hydrogen sulfide odor. Hydrogen sulfide odors were detected only at Holden and Daysland, thus showing a definite reduction in sulfate.

ALKALINITY

In most cases where samples from long detention ponds were taken the total alkalinity increased under the ice while the phenolphthalein alkalinity disappeared. Summer samples had lower total alkalinities but there was phenolphthalein alkalinities present. The alkalinities of short detention ponds were at the same level regardless of the season.

The levels of alkalinity varied from one place to another but this was mostly due to the original alkalinity of the water supply.

CHLORIDES

Since chloride ions are not affected appreciably by natural chemical or biological action their concentrations in the ponds are dependent upon evaporation and dilution of the liquid and also the initial content of the raw sewage. Removal of the ion is by seepage or effluent discharge. In this part of the country, concentration may increase considerably in the winter when thick ice layers are obtained.

In most cases in this project concentrations of approximately 100 ppm were found in the ponds. This indicates that there were increases of 5 to 10 times the water supply concentrations by the addition of raw sewage. It may also be noted that the pond chloride concentration was approximately the same as that for the raw sewage. Only one pond system, at Holden, did not follow the above trend. In this case, concentrations of 300 to 500 ppm were obtained.

whereas the incoming sewage had a concentration of approximately 100 ppm. At the present time no definite explanation is available for the differences in concentrations of chloride between the pond and incoming sewage, but it is quite possible that leaching of the soil occurs.

PART II

A MICROBIOLOGICAL STUDY OF SEWAGE LAGOONS

LOCATED IN NORTHERN ALBERTA

A MICROBIOLOGICAL STUDY OF SEWAGE LAGOONS LOCATED IN NORTHERN ALBERTA

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FINAL REPORT OF A MICROBIOLOGICAL STUDY OF SEWAGE LAGOONS LOCATED IN NORTHERN ALBERTA

INTRODUCTION

On May 20th, 1958, a joint investigation was commenced by members of the Department of Bacteriology of the University of Alberta in conjunction with members of the Division of Sanitary Engineering of the Department of Public Health of the Province of Alberta, with the object of studying a number of sewage lagoons located in Northern Alberta. Study of the microbial flora in samples obtained from the various sewage lagoons was done in the Department of Bacteriology. Various chemical tests were done on the samples by members of the Sanitary Engineering Division. The lagoons under investigation varied in construction and efficiency, and it was hoped that a study of the microbial flora present in these lagoons would reveal not only a seasonal fluctuation of the flora but also peculiarities or differences which might explain the difference in operating efficiency of the lagoons.

No similar study of the microbial flora of operating sewage lagoons in this part of the world, or in climatic conditions similar to those existing in Western Canada had been reported. Therefore, the initial phase of our investigation of necessity involved the establishment of a method of obtaining proper samples; a sampling routine; and suitable laboratory techniques for the examination of the samples. The details of these technical problems have been fully discussed in the thesis presented by Mr. Arthur Garden of the University of Alberta for the degree of Master of Science. Suffice it to say that a special sampling device was constructed for the purpose of obtaining sewage samples from two levels (namely, one foot below the surface, and one-half foot above

the bottom of the lagoon) without mixing of sewage from above or below. The temperature of the sample at the time of sampling was determined.

Samples were always to be taken from the same location in the lagoon (a procedure which was not always adhered to as will be seen in the discussion of our results). Samples were to be taken periodically at approximately two-week intervals. This procedure was followed until the latter part of the investigation when a longer period of time was allowed to elapse between sampling. After initial instruction by members of the Department of Bacteriology as to the method of sampling, members of the Sanitary Engineering Division obtained the samples and transported them to the Laboratory of the Department of Bacteriology where the microbiological examinations were done.

In the laboratories of the Department of Bacteriology, a viable or living count of the aerobic bacteria present in 1 ml. of the sample was determined at incubation temperatures of 37.5°C, 20.0°C, and 7.0°C. The number of viable anaerobic bacteria per ml. was determined at an incubation temperature of 37.5°C. The most probable number of coliform bacteria was determined for each sample. The total number of algae per ml. of sample and the predominating kind of algae was determined. Periodically, samples from all lagoons were examined for possible human pathogenic (disease-causing) bacteria. The laboratory procedures employed were all standard procedures and have been fully described in the thesis previously mentioned.

Sewage lagoons investigated in this manner were located at Holden, Daysland, Bruderheim, Lacombe, Stony Plain and Drayton Valley.

The results of the microbiological study of 180 samples taken from the various lagoons are presented graphically in Figures 1 to 28. The actual enumeration of the various micro-organisms present in these samples are presented in Tables I to XVIII. The dates of sampling for each lagoon are given in Appendix A. The total number of microbiological examinations done in the laboratory was 1,008.

RESULTS

The microbiological details of top and bottom samples taken from the various lagoons under study are presented graphically in Figures 1 to 8 and 21 to 28. Each of these figures show the number of aerobic bacteria which grew in the laboratory at the incubation temperatures employed (namely, 37.5°C, 20.0°C and 7.0°C), when one ml. of the sample was tested. The number of anaerobic bacteria per ml. of sample growing at 37.5°C is also shown. In the figures the most probable number of coliform bacteria is given for 1 ml. of sample. The total number (living and dead) of algae per ml. of sample is shown. Tables I to XVIII give the exact figures obtained in the enumerations presented in the graphs. Figures 9 - 20 contrast the viable bacteria counts obtained at 37.5°C, 20.0°C and 7.0°C for the four principle lagoons studied (namely, Holden, Daysland, Bruderheim and Lacombe), and the algae counts.

Tables XIX - XXVII give the various environmental conditions (temperature, etc.) existing for each lagoon on the date each sample was taken.

Figures 29 and 30 present graphically the pH and the dissolved oxygen existing in the four principle lagoons on the various sampling dates.

Appendix B shows the predominating genera of algae present in top and bottom samples taken from each lagoon throughout the sampling period.

DISCUSSION OF INDIVIDUAL LAGOONS

For the purpose of discussing the microbial populations present in individual lagoons, the counts from top and bottom samples for each sampling date have been averaged. When only a single sample from either the top or bottom of the lagoon is available, this count has been used in the discussion. The counts which differ markedly from immediately previous and subsequent counts for the same lagoon are discarded, since they are considered to be due to experimental error. Each microbial count is approximated to the nearest power to the base 10. The latter figure is used to describe the population curve.

Whenever the dilution of the sample is inadequate to determine the MOST PROBABLE number of coliforms, previous and subsequent counts are considered to determine an approximate value.

The environmental features are considered in relation to microbial populations.

GENERAL DISCUSSION OF ALL LAGOONS

The microbial populations of all lagoons are compared during a period of standard operation. This period lasts for 12 months between the times of drainage in November of each year (the actual standard period of operation was from November 1958 to November 1959). During the period

of standard operation there was no change in the method of operating the lagoon. To show their relative functional capacity, all lagoons are compared during this standard period specifically for the late winter of 1959 (from February 17th to March 10th), and the late summer of 1959 (from August 27th to September 1st).

Microbial populations are discussed in four distinct groups. The bacteria are considered in three groups:

(1) The sum of aerobes at 7°C, 20°C and 37.5°C:

(2) The anaerobes:

(3) The coliform group.

Finally, the total count of algae is given.

ADDITIONAL INVESTIGATIONS

In addition to the major investigation previously described, the following experiments were done.

A. A laboratory research project using pilot or scale model lagoons maintained under standardized conditions throughout the test period. The results are presented in Tables XXVIII and XXIX.

B. Investigation of microbial populations in lagoon effluent at various locations along the drainage course. The results are presented in Table XXX.

C. Investigation of microbial populations in ice cover of a sewage lagoon. Results are presented in Table XXXI.

D. Spot test investigation of microbial populations in sewage lagoons located in northern Alberta but widely separated geographically. The results are presented in Table XXXII.

HOLDEN SEWAGE LAGOON

The detention time for the storage lagoon at Holden is calculated to be 274 days, i.e., the time required to fill to the maximum possible depth of 4 feet. The lagoon is not used to its maximum capacity because it is drained to the one foot level in April and November of each year. Since only 3 feet of depth is actually used, the detention time is really 205.5 days. (Appendix B). There are two periods when the lagoon is filling with sewage fluid, one from April to November through the warm seasons when there is open water, and the other throughout the winter season from November to April when most of the water is transformed into the ice cover. The thickness of the ice increases throughout the winter (from 0 inches to 24 inches) and varies from winter to winter. The liquid portion also varies in depth (January/59 - 6 inches; January/60 - 16 inches).

Samples were taken from the lagoon during the 20 month period June 4/58 to January 6/60. (Appendix A). When the depth of the liquid became too shallow, following the draining of the lagoon to the one foot level, or after the formation of the ice cover, only single samples were taken. Both top and bottom samples were taken in the summertime when the liquid increased in depth from 2 feet to 3.3 feet. The samples were taken at a location in the body of the lagoon 40 feet from the west bank. (Appendix C).

The environmental factors were determined throughout the investigation. (Table XIX). The dissolved oxygen was measured by the Winkler method. During the warm months the concentration was quite

variable. The highest concentration 18.8 ppm of dissolved oxygen occurred in July/58. In November/58 after 4 inches of ice formed over 8 inches of liquid and the lagoon temperature was 0.75°C there was 9.7 ppm of dissolved oxygen present. During the winter subsequent samples contained no measurable dissolved oxygen. The temperature of the sewage fluid at the time of sampling was the same for both the top and bottom samples. The maximum temperature measured was 25°C which occurred in July/58. The minimum temperature, 1° - 0°C occurred during the winter from November/58 to February/59. The range of pH varied between 9.6 in July/58 and 7.6 in March/59, thus the sewage fluid was always alkaline at the time of sampling. However, it was more alkaline during the warmer months.

The aerobic viable bacteria counts at the incubation temperatures of 7°, 20°, and 37.5°C followed the same general yearly pattern of fluctuation. (Tables I, II: Figures 1, 2, 10 - 20). This pattern appeared to follow the draining and the filling routine of the fluid volume of the lagoon. Following the drainage of the lagoon to the one foot depth of liquid in April/58 the counts were at their highest. After the sewage filled the lagoon to the depth of 3.3 feet in September/58, the counts were at their lowest value. During the winter period as sewage was filling the lagoon and the liquid was being transformed into ice, the counts continued to increase to high values again. While the lagoon was being filled to a depth of 12 inches under an ice cover of 18 inches by February/59, the count of anaerobes increased by 100-fold and the aerobes decreased in count. The aerobes returned to the January/59

level by March/59. After the ice melted the lagoon was drained to the one foot level in April/59. In May/59 when a full year of investigation was completed the counts of the aerobes were again near the high counts of June/58.

From June/58 to the middle of July/58 the coliforms decreased to their lowest value near 10^1/ml. From July to March/59 near the end of the winter and under the cover of ice the coliforms increased to 10^4/ml.

The viable count of anaerobic bacteria grown at 37.5°C followed a similar fluctuation, but the minimum count came at the end of July/58 at the level of 10^2/ml. During the fall and early winter, as the lagoon was drained and filled again and as ice formed on the surface, there was a steady increase in count to 10^5/ml. by January/59. The count remained high and steady until May/59. At this time the count was again similar to June/58.

The general trends shown in aerobic, anaerobic and coliform counts from June/58 to May/59 were repeated the following year.

The algae maintained a high count of 10^5 to 10^6/ml throughout the investigation except when they were too numerous to count (February/59) or not evident (March/59) in the sample.

During the summer of 1958 from June to September the crustacean, daphnia, and the protozoan, paramecium, were present.

DAYSLAND SEWAGE LAGOON

A short detention lagoon which takes only 6.2 days to fill to its maximum depth of 6 feet is used as a sludge pit for the raw sewage received from the town of Daysland. After the lagoon is filled the sewage liquid overflows continuously into a slough. Sludge is filling the lagoon at a rate of 12 inches per year, decreasing the detention time. The maximum depth at the beginning of the sampling period in September/58 was 46 inches and the actual detention time was 4.1 days. When the final sample was taken in January/60 the depth was only 30 inches and the overflow occurred after 2.6 days of filling the lagoon. (Appendix B).

During the winter the temperature in this lagoon is maintained at a higher level and thus only a thin ice cover forms. In January/59 the temperature was 3°C when the liquid depth was 42 inches and the ice was 9 inches thick. In January/60 the temperature was 1.5°C, the depth 30 inches and the ice cover was only 7 inches thick. No dissolved oxygen was detected by the Winkler method throughout the investigation. Only one sample in September/59 had an acid reaction (pH 6.95); all others were alkaline within the range of pH 7.9 to 7.25. Both the top and bottom samples had the same temperature. The maximum temperature recorded, 15.5°C, occurred in September/58 and the minimum temperature during the winter of 1958 was 3°C. (The lowest temperature, 1.5°C, was in January/60 when the liquid was 30 inches deep). (Table XX).

Samples were taken from the lagoon during the 17 month period from September 16/58 to January 27/60 (Appendix A). The samples were

taken from the body of the lagoon in the northwest corner (Appendix C). The samples were taken between noon and 2:30 p.m. They were taken once a month from September/58 to March/59; then again in May and September of 1959 and finally in January 1960.

The microbial counts were nearly constant and remained high with minimal fluctuations throughout all the seasons. (Table III, IV; Figures 3, 4, 10-20).

Aerobic bacteria grown at 7°C and 20°C maintained a high count slightly above 10^6/ml. throughout the investigation. The aerobes grown at 37.5°C were at a slightly lower count during the same period. From September/58 to January/59 the count decreased from 10^6 to near 10^5/ml. and maintained a steady count until January/60 though the plate count fluctuated slightly. The coliform count was never less than approximately 10^4/ml. Through the fall of 1958 the Most Probable Number was probably greater than 10^5/ml. (the count of the February/59 sample). Then the coliform count decreased to between 10^5 and 10^4/ml. and maintained a steady count greater than 10^4/ml. until January/60. From September/58 until the ice formed in November the anaerobic count was 10^6/ml. From December/58 to January/60 the count fluctuated about 10^5/ml. The total algae count was low in September/58 (10^5/ml). In October/58 during the open water and then in November/58 when the ice had formed there were too few algae to count accurately. During the period from December/58 to February/59 when there was an ice cover and the liquid averaged a temperature of 3°C and in March/59

when there was open water and a temperature of 5°C the algae were too numerous to count (greater than 8.0×10^6/ml) and the odor was that of a pig-pen. From May/59 until January/60 the total algae count averaged 10^6/ml. and the normal sewage odor was present. (Appendix E).

BRUDERHEIM SEWAGE LAGOON

During the summer and winter of 1958 the Bruderheim lagoon was used as a storage lagoon and during the warm season of 1959 as continuously overflowing lagoon. The calculated detention time is 200 days to fill the lagoon to the maximum possible depth of 4 feet. The actual storage time of this lagoon is 150 days when the lagoon is drained to the one foot level and only the top 3 feet are used. (Appendix B). In the first warm season the lagoon was filled to the depth of approximately 3.5 feet from April to November/58 and then drained. During the winter of 1958 the lagoon was used to store the sewage fluid, allowed to fill to the maximum capacity of 4 feet and then allowed to overflow during the following warm season of 1959. The overflow continued until November/59 when the lagoon was drained to the one foot level. During the final winter the lagoon was again filling as a storage lagoon.

Sampling occurred over a period of 19 months from July 3/58 to January 5/60 (Appendix A). The samples were taken between 11:00 a.m. and 3:00 p.m. from the outlet location at the middle of the north bank (Appendix C). The use of the lagoon from June/58 to June/59 could have been considered as a full year of routine operation except that the lagoon was allowed to overflow during the open water season of 1959. However, a full sampling year with a standard routine of operation occurred between the time of drainage of the lagoon in November/58 and in November/59. The study from the microbiological point of view will be considered during this time.

The environmental factors before November/58 were not considered since they were incomplete up to this date. After November/58 the environmental factors were as follows: No measurable dissolved oxygen was evident in any of the samples. The maximum temperature recorded in the lagoon was 20°C in July/59. The minimum temperature observed was 0.25°C in November/58. The pH was alkaline during the warm seasons, fluctuating about 7.7, while under the ice the pH was 7.0 and as low as 5.95 (Table XXII).

Only single samples were taken during the winter storage period of 1958. As the sewage liquid filled the lagoon an ice cover formed probably beginning at the time of the November/58 sample. The ice increased in depth to 3.5 feet by March/59. The liquid remained at the one foot level and then decreased to 0.5 feet in March/59. The liquid was acidic, had a pigpen odor and was at a temperature of 0.5°C during this period.

During this storage period the 20°C aerobes maintained a count slightly greater than the 10^6/ml. level and the 7°C aerobes fluctuated about 10^6/ml. (Tables V, VI: Figures 5, 6, 10-20). The 37.5°C aerobes fluctuated within the 10^6 to 10^5/ml. range. The anaerobes which were at 10^6/ml. in November/58 decreased to 10^5/ml. during January and February/59 and then returned to 10^6/ml. in March/59. The Most Probable Number of coliforms was near to 5.0 x 10^4/ml. throughout the winter. The algae were too numerous to count (greater than 1.6 x 10^6/ml). From November/58 to March/59,

though the count decreased to 10^6/ml. in February/59. (Appendix E).

Four samples were taken during the period of overflow in the open water season. Both top and bottom samples were taken at the outlet region. The period ended with drainage of the lagoon to the one foot level in November/59.

All the microbial counts were decreasing when the June/59 sample was taken. On this date the aerobes reached the lowest count of the open water period. The 7°C aerobes decreased to slightly above 10^5/ml. and then increased to 10^6/ml. level by October/59. After fluctuating to a count slightly greater than 10^5/ml. the 20°C aerobes returned to a steady count of approximately 3.0×10^6/ml. until October/59. The 37.5°C aerobes fluctuated from 10^4/ml. in June/59 to 10^6/ml. in August/59 and then decreased to slightly above 10^5/ml. in October/59. The anaerobes continued to decrease to a minimum count of 10^3/ml. in August/59 and by October/59 the count had increased to slightly above 10^6/ml. In August/59 the Most Probable Number of coliforms reached the lowest count (near 10^3/ml.) and then increased towards 10^4/ml. by October/59. The total count of algae fluctuated near 10^7/ml. in June and July/59 and then became too numerous to count by August and October/59.

During the winter of 1959-60, which was milder than the previous winter, the sewage liquid filled to a greater depth (2 feet) than in February/59 (1 foot) and the ice was only 1.5 feet by January/60 as compared to 3 feet in February/59. By January/60 most microbial

counts were lower than in January/59. The aerobes incubated at $7^{o}C$ and $20^{o}C$ were between 10^{5} and 10^{6}/ml. The 37.5^{o} aerobes, anaerobes and coliforms were lower than the previous January counts by one-tenth. The total algae count was near 10^{7}/ml. by January/60.

LACOMBE SEWAGE LAGOON

At the Lacombe raw sewage lagoon a complete year of a standard routine of operation occurs between November of each year. In the winter the lagoon is used for the storage of sewage and in the summer during the open water seasons the lagoon is allowed to overflow continuously until it is drained in November.

The calculated detention time for this "long detention" lagoon is 204.4 days, i.e., the time required to fill to the maximum depth of 5 feet. Since the lagoon is drained to the one foot level in November, the filling time is actually about 165 days, and an overflow occurs for the remaining 200 days of the year (until drained again in November of the next year). (Appendix B). During the storage of the sewage liquid in the winter of 1958-59 the liquid was transformed into the ice cover. The liquid level decreased from 12 inches to 5 inches by the end of November/58 and 7 inches of ice were formed. From November/58 to February/59 the ice and liquid increased to a depth of 15 inches each. In March/59 the water was open and overflowed when the depth reached 5 feet. Overflow continued until drainage time in November/59 and this completed the standard period of operation.

Sampling occurred for a period of 19 months from July 3/58 to January 13/60. (Appendix A). The majority of samples were taken between 10:30 a.m. and 1:00 p.m. Both top and bottom samples were taken during the overflow seasons, but after the November drainage of the lagoon and the formation of the ice cover only single samples were

taken. The location for sampling was in the body of the lagoon approximately 40 feet from the south bank and south of the inlet which is in the bottom at the centre of the lagoon. (Appendix C). This sampling position was used from July 3/58 to March 24/59. Samples taken from June 3/59 to January 13/60 were obtained at the outlet region. Since the only constant variable, the position of the sample was changed the study of the function of the lagoon from a microbiological point of view could not be completed on a yearly basis. The microbiological changes were then determined at the new position in the outlet region under completely new micro-environmental conditions. Thus the microbial counts will be considered under two separate headings according to the position of sampling.

The Microbial Counts During Sampling within the Body of the Lagoon from July/58 to March/59: (Tables VII, VIII; Figures 7, 8, 10-20).

The counts of aerobes grown at 7°, 20° and 37.5°C followed a similar pattern even though the lagoon was drained in November/58. The anaerobes and coliforms showed the greatest increase in count throughout the summer and winter of 1958. The 7°C aerobes increased from 10^5 to 10^6/ml. from July to October/58 and then averaged 10^6/ml. until December/59. The count decreased from January to March/59 to about 10^5/ml. The 20°C aerobes increased from July to September/58 from 10^5 to 10^6/ml. and then fluctuated about the 10^6/ml. level until March/59. The 37.5°C aerobes also increased from 10^5 to 10^6/ml. to December/58. The count then decreased to 10^5/ml. by March/59. The result for anaerobes in the July 24/58 samples was discarded as it was considered

to be due to experimental error. The anaerobic count increased from 10^2/ml. in July to 10^5/ml. in October/58. From one open water period in the late fall of 1958 to the next open water period in March 1959 the anaerobic count remained steadily near 10^5/ml. although the January/59 count was close to 10^4/ml. The Most Probable Number of coliforms was 10^2/ml. from July to the beginning of August/58. The count increased rapidly at the end of August/58 and probably reached a value of 10^4/ml. or greater (based on the trend shown during the following winter), by November/58. The total algae count was slightly below 10^6/ml. until January/59 when the algae were too numerous to count. No count was determined in February/59, but by March/59 with the open water the count was again near 10^6/ml. (Appendix E).

The Microbial Counts During Sampling at the Outlet Region from June/59 to January/60:

The lagoon was overflowing at a depth of 5 feet during sampling from June to September/59. The final sample in January/60 was taken under ice 15 inches thick and from a liquid depth of 9 inches. No sample was taken just before the drainage of the lagoon in November/59 which could have completed a year of standard operation. The 7°C, and 20°C aerobes, the anaerobes and the algae from the outlet samples all followed a similar pattern with their lowest counts in September/59. The 7°C and 20°C aerobes decreased from 10^6/ml. in June/59 to approximately 10^5/ml. in September/59. The aerobes of the 7°C group then remained constant until January/60, but the 20°C group increased

slightly in plate count. The anaerobes followed a similar pattern decreasing to the 10^4/ml. level but returning to a level near to but slightly above that which occurred in January/59. The total count of algae followed the same pattern, but remained within the range of 10^6 to 10^5/ml. The aerobes incubated at 37.5°C decreased during June and July/59 (from 10^6 to 10^5/ml.) and then remained slightly above 10^5/ml. until January/60. The Most Probable Number of coliforms fluctuated greatly from one sampling date to the next. The June and September/59 counts were similar and low (10^3/ml.) while the July/59 and January/60 counts were similar and high (above 10^4/ml.).

During the period of July/58 to January/59 when samples were obtained in the body of the lagoon all microbial counts showed a steady increase. In 1959 the microbial count of samples from the outlet region decreased during the period June to September and then increased until January/60 when values similar to those obtained in January/59 were again recorded.

The pH was always alkaline in this lagoon. (Table XXII). The pH in the body of the liquid in the lagoon was high during the open water season of 1958, varying from 10.1 to 8.9, and under the ice cover the pH of the liquid remained alkaline with values from 8.25 to 7.55. At the outlet sampling location the pH was only 8.7 to 9.4 during the summer and was 7.5 during the winter of 1960. The dissolved oxygen had a maximum value of 25.6 ppm in July/58. Dissolved oxygen was present until October/58. During the period of ice cover from November/58

until the open water in March/59 no dissolved oxygen was detected by the Winkler technique. Excess dissolved oxygen was present in the sample at the outlet taken during the summer of 1959 (20.4 ppm) but no dissolved oxygen was detected at this location in January 1960. The maximum temperature recorded in the body of the lagoon was 22°C during July and August/58. While the ice cover was present the temperature ranged from 1° to 0°C. In March/59 the temperature was 2.5°C and there was no ice cover. Temperatures taken at the outlet sampling location fluctuated in a similar manner.

STONY PLAIN SEWAGE LAGOONS

This lagoon system consists of three short detention lagoons and one long detention lagoon. The sewage liquid flows continuously through the first three lagoons. Lagoons number 1 and 2 are constructed with the same dimensions having a depth of 5 feet and a calculated detention time of 0.93 days. Lagoon 3 has a depth of 5 feet and a calculated detention time of 2.6 days. The fourth lagoon which is used as a storage lagoon was constructed more recently and has a depth of 6 feet and the calculated detention time is 187 days.

Only one sample was taken from the first lagoon while all three lagoons were in normal operation. This sample was taken from the top on October 27/58. The microbial counts obtained from this sample are shown in Table XI, and the various environmental factors in Table XXIII.

No sampling was done in lagoon 2. From approximately the middle of August to September 30/58 sewage flow occurred through lagoons 1 and 2 into a ditch by-passing lagoon 3. On October 27/58 and following that date sewage again flowed through all three lagoons continuously.

The third short detention lagoon was not in continuous operation. The inlet was plugged and the lagoon by-passed for the months of August and September/58. During this time samples were taken at the outlet region although there was no inflow or overflow. The stagnant liquid decreased in volume by evaporation only. No new nutrients or fresh inoculum of micro-organisms were added to the sewage fluid during this time. Results obtained from samples taken from this lagoon during

August and September/58 demonstrate what occurs when sewage fluid is stored during summer. During this stagnant period the numbers of aerobic bacteria obtained at 7°, 20° and 37.5°C decreased in a similar manner. (e.g., 7°C; from 10^6 to 10^4 ml. and the 20°C; from 10^7 to 10^5/ml.). The 37.5°C aerobes showed the greatest change in count. The top sample decreased from 10^7 to 10^5/ml., while the bottom sample decreased from 10^7 to 10^2/ml. The coliforms showed a decrease in numbers similar to but less pronounced than the aerobes at 37.5°C. The anaerobes showed a 10-fold increase in count during the same period. The total algae count decreased from 10^6 to 10^5/ml. and at the end of the period were too few to count accurately.

The environmental factors were measured during the months the lagoon fluid was stagnant and evaporating. On August 13/58 the temperature was 21.5°C. The pH was 7.7 and there was 10.5 ppm of dissolved oxygen present. In the next two samples the temperature was 16.8°C and 14.5°C and the fluid had an alkaline reaction at pH 7.6. No dissolved oxygen was detected in these samples. When the final sample of the stagnant period (September 30/58) was taken the temperature was 7°C, the pH alkaline at 8.2 and dissolved oxygen was again present at 17.4 ppm.

When the October 27/58 sample was taken the 3 lagoons were again functioning in series. The third lagoon was flowing into a ditch. Continuous overflow occurred through the winter. The ice cover was 8 inches thick and the liquid 4 feet deep.

The sample of October/58 shows the recovery of the third lagoon as a result of resumption of normal operation. Top samples obtained from the first and third lagoon contained comparable microbial populations. No algae were evident in the first lagoon, but they were present in the third lagoon though too few to count accurately. There was only 0.5°C difference in temperature and no dissolved oxygen was present in either lagoon. The pH decreased from 7.6 in the first lagoon to 7.25 in the third lagoon.

During the period of standard routine of operation from October/58 to December/60 both top and bottom samples were obtained from the outlet region at the north bank. In October/58 only a top sample and in March/59 only a bottom sample was taken.

All the microbial counts remained at relatively high values though there was a gradual decrease from the fall of 1958 to the winter of 1959. The aerobes grown at incubation temperatures of 7°, 20° and 37.5°C. decreased in a similar pattern from the high of 10^6/ml. in October/58 fluctuating between 10^6 to 10^5/ml. until December/60 when the counts were near 10^5/ml. The anaerobes increased to their maximum count (10^7/ml.) in December/58 then decreased to 10^4/ml. in March/59 and fluctuated between 10^4/ml. to 10^5/ml. until December/60. The Most Probable Number of coliforms in March/59 was 10^5/ml. therefore it is considered that the coliform count probably had reached this value in October/58 after the continuous overflow commenced. The count decreased from 10^5/ml. to 10^4/ml. by June/59, remained steady until

August/59 and then decreased to slightly below 10^4/ml. by December/60. The algae were too few to count accurately in the October/58 sample, but by December/59 the count was 10^6/ml. in 4 feet of liquid covered with 8 inches of ice. The algae decreased to slightly above 10^5/ml. by March/59. No results were obtained in June/59. In August/59 the algae were too few to count accurately, but by December/60 the count was 10^7/ml. (liquid 4'; ice 8").

The long detention lagoon, the fourth lagoon, was brought into service to store sewage flowing continuously from the third short detention lagoon. The initial filling began in April/59 and continued until the Spring of 1960 when the lagoon was drained to the one foot level.

Top and bottom samples were taken at the outlet region on the north bank on August 25/59 and on December 9/59.

The microbial counts of all groups were similar in the top and bottom sample in August/59. On December/59 when the final samples were taken, the aerobes at 7°, 20° and 37.5°C, all had a 10-fold greater count in the top sample, than in the bottom sample, while the other microbial groups had similar counts in both samples. At this time the lagoon was stagnant with 4.5 feet of liquid under 1 foot of ice. The temperature of the liquid was 0.5°C. Nutrients and organisms were being continuously added to the lagoon by way of the influent. During the period August to December/59 all the microbial counts increased greatly. Aerobes and anaerobes incubated at 37.5°C showed a 10-fold increase. The aerobes of 7°C and 20°C and the coliforms increased

100-fold. The greatest change however was shown in the total algae count.

The counts for all microbial groups were much lower in the fourth lagoon than in the third lagoon in August/59. By December/59 the microbial populations of both the third and fourth lagoons had increased, however, the rate of increase was more rapid in the fourth lagoon.

Environmental factors in lagoons 3 and 4 showed very significant alterations over the period August/59 and December/59. In August/59 the change in each factor between lagoons 3 and 4 was as follows: The temperature increased from 12°C to 14°C; the pH increased from 7.4 to 8.4. The dissolved oxygen increased from 0 to 8.8 ppm. The depth of liquid was 5 feet and 4 feet respectively in December/59 the changes between lagoon 3 and 4 were as follows: The temperature decreased from 3°C to 0.5°C, the pH increased from 7.5 to 7.75. The most significant change was the concentration of dissolved oxygen. The third lagoon had no dissolved oxygen in 4 feet of liquid covered with 8 inches of ice whereas the fourth lagoon with 4.5 feet of liquid and 1 foot of ice contained 6.3 ppm of dissolved oxygen.

DRAYTON VALLEY SEWAGE LAGOONS

Three long detention lagoons in series constitute the sewage treatment plant at Drayton Valley. In November each lagoon is drained to the 1 foot level so that the operational depths are 4', 4', and 3' for lagoons 1, 2 and 3, though the actual depths are 5', 5' and 4' respectively. The calculated detention times are 51.8, 32.9 and 25.6 days, but for reasons given above (Appendix B) the actual detention times are 41.4, 26.3 and 26.7 days respectively. The capacity of the first lagoon is continuously decreasing because it is filling with sludge. The lagoons become storage lagoons during the winter after being drained to the 1 foot level in November. The first lagoon is stagnant though it continues to receive raw sewage. The subsequent lagoons are stagnant and receive no new nutrients or inoculum of microorganisms until the preceding lagoon fills to overflowing. After the third lagoon is filled, the fluid is allowed to overflow until the following November when each lagoon is drained.

Sampling was carried out at Drayton Valley for 17 months from (Appendix A) October/58 to February/60. During the period from April/59 to August/59 no samples were obtained for a microbiological analysis. Usually top and bottom samples were taken at the outlet region of each lagoon until drainage when the liquid was too shallow or until the formation of the ice cover. Samples were taken at various times of day from 11:30 am to 3:30 pm.

From the microbiological point of view the lagoon will be described only during the standard period of routine operation, from November/58 to November/59. The period from November/59 to the middle of

February/59 was the period of storage for the whole series of lagoons. No samples were obtained during this period so that the functional capacities of each lagoon are unknown.

The period of continuous overflow began in February/59 and lasted until November/59.

During the winter samples were taken in February and March/59.

Top and bottom samples were taken from lagoon 1 which had a depth of 4 feet and only 1 foot of ice. The February sample had a temperature of 1°C and the March sample was 2°C. No dissolved oxygen was detected by the Winkler method. The pH was 7.5 in both samples.

Only single samples were taken from lagoon 3 since the liquid depth was 2.5 feet and the lagoon was covered by ice 2.0 feet thick. The temperature of the February sample was 0.5°C and the March sample was 1°C. No dissolved oxygen was detected in either sample. The pH was 7.6 in February and 7.7 in March/59.

During the late winter of 1959 the viable bacteria counts remained nearly steady in lagoon 1. The aerobes at 37.5°C and at 20°C stayed slightly above 10^5/ml. and 10^6/ml. respectively. The aerobes at 7°C fluctuated about 10^6/ml. The anaerobes increased during this period from 10^4 and 10^5/ml.

No further samples were taken until the end of the summer of 1959 (September 16/59) so that the functional capacity of the lagoons during the open water period from April to September/59 is unknown.

A top and bottom sample was taken on September 16/59 one and a

half months before the lagoons were drained to the one foot level in November/59. On this date samples were taken from all three lagoons for the first time. The samples were taken between 11:15 and 11:45 AM.

The temperature in lagoon 1 was 11°C. Lagoon 2 and 3 both had a temperature of 12°C. The first two lagoons were more alkaline and had the same pH (9.1) whereas lagoon 3 had a pH of 8.55. There was little difference between lagoons with regard to dissolved oxygen, e.g., 1.7 ppm for lagoon 1; 1.4 ppm for lagoon 2; and 1.2 ppm for lagoon 3.

In lagoon 1 only a top sample was taken. The aerobes at 7°C had a count slightly above 10^5/ml. whereas both the 20°C and 37.5°C groups were slightly less than 10^5/ml.

The counts in lagoon 2 were at a lower level except for the anaerobes which remained at 10^2/ml. The aerobes at 7°C were at the 10^3/ml level whereas the 20°C and 37.5°C groups were at the 10^4/ml level. The coliform count was lower (10^1/ml.).

In lagoon 3 the aerobes at 7°C and 20°C were both slightly below 10^3/ml. The aerobes at 37.5°C maintained a high count similar to the previous lagoon at the level of 10^4/ml. Both the anaerobes and the coliforms had the lowest and the same count of 3.5×10^0/ml. In this sample the algae were too few to count accurately.

The extent of stabilization of the microorganisms within each lagoon during this period of standard operation from November/58 to November/59 was greater in each subsequent lagoon.

The stage of stabilization was greater in lagoons 1 and 3 in the summer than during the previous winter. Lagoon 3 was at a more stabilized state from the microbiological point of view than lagoon 1 and 2.

GENERAL DISCUSSION

1. STRUCTURE AND OPERATION OF THE LAGOONS

The lagoons may be classified according to their structure (Appendix C) and their operational capacities. (Appendix B). None of the lagoons are identical in any of these features. The only common feature is their function to stabilize the organic matter and the microorganisms present within the lagoon.

The lagoons may be classified according to the actual routine of operation (Appendix D) used during the investigation of the standard period which occurred between November/58 and November/59. Only three lagoon systems (Holden, Daysland, Drayton Valley) maintained a standard routine of operation throughout our investigation. Alterations from a standard routine of operation occurred in all others. The third lagoon at Stony Plain was by-passed from August to September/58. Bruderheim lagoon was changed from a storage lagoon in 1958 to an overflow lagoon during the summer of 1959; and drained in April/58 but not April/59. Lacombe lagoon was drained in April/58 so that the overflow occurred from July to November/58; but in 1959 the lagoon was not drained in April so that overflow occurred throughout the open water season.

2. STABILIZATION OF THE MICROORGANISMS

The influence that the lagoons may have upon the survival and the sedimentation of the microbial populations present within the sewage liquid may be determined by comparing the counts of the microbial populations during the periods of maximum or minimum physico-chemical environmental conditions as occurs in the summer and winter seasons. Such comparison

was possible since the standard period of routine operation of each lagoon occurred from November/58 to November/59 and samples were taken from each lagoon in comparable seasons. Winter samples were taken in the late winter of 1959 from February 17 to March 10/59. During this time the ice cover reached a maximum thickness, hours of sunlight were shortest and the temperature of the lagoon was lowest. Also this was the final stages of storage for storage lagoons and a month before the ice melted from the continuously overflowing lagoons. Summer samples were taken in the late summer of 1959 from August 25 to September 16/59 when there was open water and a continuous overflow of sewage liquid from all but the Holden lagoon. At this time the hours of sunlight were longest and the water temperature of the lagoon approached the maximum for the year.

3. THE COMPARISON OF THE MICROBIAL POPULATIONS OF EACH LAGOON DURING THE STANDARD PERIOD FROM THE LATE WINTER TO LATE SUMMER of 1959

I. A SINGLE LAGOON

A. Standard Routine of Operation Throughout the Investigation.

1. HOLDEN

In this long detention lagoon, which is used for raw sewage storage during the winter and summer and is drained before each period, some reduction of the microbial populations occurred within the body of the lagoon. There was a one-tenth reduction of the viable bacteria, The aerobes decreased from 10^6 to 10^5/ml. The anaerobes and the coliforms each decreased from 10^4 to 10^3/ml. The total algae count stayed at 10^6/ml.

2. DAYSLAND

This continuously overflowing lagoon has a short detention period which is continuously becoming shorter due to the deposition of sludge. In the body of the lagoon during the standard period the aerobes maintained a count of 10^6/ml. The anaerobes maintained a steady count (10^5/ml.). The coliforms were reduced from 10^4 to 10^3/ml. The total algae count stayed at 10^6/ml.

B. Routine of Operation Altered During the Investigation.

1. LACOMBE

Lacombe has a long detention lagoon used for storage of raw sewage during the winter and overflow during the summer with drainage each November. Previous to the period of standard operation the lagoon was drained in November and April allowing only a short overflow period from July to November/58. The location of sampling was changed from the body of the lagoon during the winter storage period to the outlet region during the summer overflow of 1959. The aerobes decreased from 10^6 to 10^5/ml. The coliforms maintained a steady count of 10^4/ml. The anaerobes decreased from 10^5 to 10^3/ml. In the summer the total algae count was 10^5/ml.

2. BRUDERHEIM

Like the Lacombe lagoon it is a long detention lagoon used for winter storage and summer overflow with drainage each November. At the beginning before standard operation, it was used as a storage lagoon like the Holden lagoon. Sampling at the outlet showed that the microbial population remained high throughout the year of standard operation. There was no reduction of the aerobic bacteria (10^6/ml.). The anaerobes decreased from

10^6 to 10^3/ml. The coliforms decreased from 10^4 to 10^3/ml. The algae were at the highest count of any lagoon; greater than 10^8/ml.

II. A SERIES OF LAGOONS

A. Routine of Operation Altered During the investigation.

1. STONY PLAIN

There are a series of three short detention lagoons which continuously overflow. The first lagoon is a sludge pit which is continuously filling with sludge. The third lagoon was stagnant until the beginning of the period of standard operation. In the third lagoon there was no reduction of the aerobes (10^6/ml) and the anaerobic count remained at 10^4/ml. The coliforms decreased from 10^5 to 10^4/ml. The total count of algae was 10^{5-7}/ml.

2. DRAYTON VALLEY

Stabilization of the microorganisms occurs in three stages in this series of short detention lagoons. During the period of standard operation this system was used for early winter storage and late winter and summer overflow. The lagoons are drained each November so that the length of the storage period for each lagoon during the early winter depends upon the time required to fill each lagoon to overflowing.

There were insufficient samples from lagoon 2 to show a comparison.

The stabilization of microorganisms which occurred between lagoon 1 in the winter and lagoon 3 in the summer was as follows:

The aerobic bacteria decreased from 10^6 to 10^4/ml. (Both the 7^oC and the 20^oC group decreased from 10^5 to 10^4/ml). The anaerobic bacteria decreased from 10^5 to 3.5×10^0/ml. The Most Probable Number of coliforms decreased from 10^4 to 3.5×10^0/ml. The total count of algae remained near 10^6/ml.

SUMMARY

The efficiency of stabilization of microorganisms in the various lagoon systems which were investigated may be summarized as follows:

1. There is no reduction in the number of viable aerobic bacteria in a continuously overflowing lagoon system which consists of a single or a series of short detention lagoons. (Daysland, Stony Plain)

2. The least reduction in the number of viable aerobic bacteria occurs in a lagoon system which consists of a single long detention lagoon used for winter and summer storage. (Holden)

3. The greatest reduction in the number of viable aerobic bacteria occurs in a series of short detention lagoons used for storage in early winter and allowed to overflow through the late winter and summer. (Drayton Valley)

4. When single long detention lagoons are used for winter storage and summer overflow and the lagoons have a different structural design and capacity (Appendix B) the greatest reduction in the number of aerobic bacteria occurs in the lagoon with the greatest surface area. (Lacombe, Bruderheim)

5. There is no reduction in the number of viable anaerobic bacteria in a continuously overflowing lagoon system which consists of a single or a series of short detention lagoons. (Daysland, Stony Plain).

6. The least-reduction in the number of viable anaerobic bacteria occurs in a lagoon system which consists of a single long detention lagoon used for winter storage and summer storage or summer overflow. (Holden, Bruderheim, Lacombe)

7. The greatest reduction in the number of viable anaerobic bacteria occurs in a series of short detention lagoons used for storage in early winter and allowed to overflow through the late winter and summer.(Drayton Valley).

8. The greatest reduction in the number of coliform bacteria occurs in a series of short detention lagoons used for storage in early winter and allowed to overflow through the late winter and summer. (Drayton Valley). Minimal reduction occurs in all other types of lagoon systems.

9. In a series of continuously overflowing lagoons the reduction in the number of viable aerobic, anaerobic and coliform bacteria is greatest when an optimal detention time is employed for each lagoon.

10. Based on Public Health Standards for the Most Probable Number of coliforms allowable in drinking water supplies the effluent from all of the lagoon systems is not satisfactory.

11. The total count of algae remains high in all lagoons winter (under the ice) and summer.

12. The culture method employed in this investigation revealed no Salmonella or Shigella.

ADDITIONAL INVESTIGATIONS

A: SEWAGE LAGOON LABORATORY RESEARCH PROJECT

INTRODUCTION

In an attempt to investigate the affect of dairy wastes on sewage lagoons a small scale or pilot sewage lagoon was set up under controlled conditions in the laboratory. The apparatus and the method of operation has been described in the report of the chemical investigation.

PROCEDURE

Various experiments were conducted using the laboratory apparatus. Initially, 100% sewage was placed in the miniature lagoons and held there for 38 days at a temperature range of 6.9° to 7.8°C. Subsequently, mixtures of sewage and milk, sewage and buttermilk, sewage and cheese whey were placed in the lagoons and held at the same temperature range for varying periods of time. The mixtures were prepared in the following proportions of sewage to dairy waste 80 to 20, 60 to 40, 50 to 50 and 20 to 80. The number of aerobic bacteria per millilitre was determined at 7°C, 20°C and 37.5°C. The number of anaerobic bacteria per millilitre was determined at 37.5°C. The number of coliform bacteria per millilitre was also determined. A total count of algae (living and dead) was also done.

Tables XXVIII and XXIX give the results obtained in these experiments.

The results shown in Table XXVIII were obtained from samples taken from Lagoon No. 1 which contained sewage plus the dairy waste in the increasing concentrations and was maintained at a B.O.D. loading equivalent to 20 lbs/ acre/ day throughout the test period. The results shown in Table XXIX were obtained from Lagoon No. 2 which contained sewage plus the

increasing concentrations of dairy waste and was maintained at a B.O.D. loading equivalent to 60 lbs/ acre/ day throughout the test period.

CONCLUSIONS

Examinations of the results presented in Table XXVIII and Table XXIX indicate first, that micro-organisms survived in relatively constant numbers when pure sewage was held in the laboratory apparatus. Secondly, the addition of dairy waste in the form of milk, buttermilk and cheese whey in concentrations varying from 20% to 80% caused no significant alteration in the number of micro-organisms present. Thirdly, there is little - if any significant difference in numbers of micro-organisms per unit volume in lagoons having a daily B.O.D. loading equivalent to 20 lbs/ acre and in lagoons having a daily B.O.D. loading equivalent to 60 lbs/ acre.

B: MICROBIAL INVESTIGATION OF EFFLUENT FROM THE SEWAGE LAGOON AT LACOMBE

Samples of the effluent from this lagoon were taken from the drainage course just before the creamery wastes enter, just after creamery wastes enter, at the first road allowance on the North-South road, and at a road allowance on the East-West road, approximately four miles from the lagoon. The number of aerobic bacteria per ml. was determined for each sample at 7°C, 20°C and 37.5°C. The number of anaerobic bacteria per ml. was determined for each sample at 37.5°C and the number of coliforms present per ml. was determined at the same temperature. A count of the algae present was not done. The results of these experiments are presented in Table XXX.

COMMENT

The decrease in the number of bacteria per ml. which occurred during the four-mile journey in the drainage course was ten-fold for all groups studied. However, the decrease in coliforms amounted to approximately 10,000-fold.

TABLE XXVIII

MICROBIAL POPULATION IN LABORATORY LAGOON NO. 1
LOADING 20 lbs./ACRE/DAY

1959 BACTERIA	Nov. 30	Dec. 7	Dec. 14	Dec. 21	Jan. 4	Jan. 13	Jan. 19
AEROBIC							
7°C	>3.0×10^6	3.0×10^7	8.5×10^6	1.5×10^7	3.6×10^6	5.8×10^5	3.0×10^6
20°C	>3.0×10^6	>3.0×10^7	4.0×10^6	8.8×10^6	9.0×10^6	1.0×10^6	3.0×10^6
37.5°C	7.9×10^4	1.3×10^4	1.6×10^5	1.8×10^5	1.9×10^5	1.9×10^5	9.5×10^4
ANAEROBIC							
37.5°C	1.1×10^5	1.3×10^4	5.5×10^3	>3.0×10^5	6.5×10^6	6.9×10^4	
COLIFORMS	9.2×10^3	>2.4×10^4	1.7×10^4	1.3×10^3	1.1×10^4	1.7×10^4	4.9×10^3
ALGAE	4.1×10^6	9.8×10^6	5.0×10^6	4.7×10^6	3.3×10^6	4.1×10^6	5.9×10^6
1960 BACTERIA	Jan. 26	Feb. 1	Feb. 8	Feb. 15	Feb. 22	Feb. 29	Mar. 7
AEROBIC							
7°C	1.5×10^7	>3.0×10^6	3.4×10^7	7.0×10^6		1.9×10^6	1.1×10^6
20°C	9.1×10^6	>3.0×10^6	3.2×10^7	1.6×10^7	9.0×10^5	1.7×10^6	1.1×10^6
37.5°C	2.7×10^5	1.0×10^5	8.0×10^5	3.7×10^4	3.5×10^5	1.4×10^5	1.0×10^5
ANAEROBIC							
37.5°C	7.5×10^4	4.6×10^3	3.0×10^5	1.0×10^5	1.3×10^5	4.0×10^4	9.5×10^3
COLIFORMS	3.3×10^3	1.7×10^3	3.1×10^2	>2.4×10^3	9.2×10^3	1.3×10^3	9.2×10^3
ALGAE	3.6×10^6	2.7×10^6	TNTC	1.2×10^7	2.0×10^6	5.1×10^6	

1960 BACTERIA	Mar. 14	Mar. 21
AEROBIC		
7°C		3.7×10^4
20°C	3.0×10^6	2.2×10^7
37.5°C	5.7×10^5	2.2×10^6
ANAEROBIC		
37.5°C	1.0×10^5	1.6×10^5
COLIFORMS	2.4×10^3	7.9×10^2
ALGAE		3.0×10^6

TABLE XXIX

MICROBIAL POPULATION IN LABORATORY LAGOON NO. 2
LOADING 60 lbs./ACRE/DAY

	1959						
BACTERIA	Nov. 30	Dec. 7	Dec. 14	Dec. 21	Jan. 4	Jan. 13	Jan. 19
AEROBIC							
7°C	$>3.0\times10^6$	1.0×10^7	8.5×10^6	1.7×10^7	4.8×10^5	$>3.0\times10^6$	$>3.0\times10^6$
20°C	$>3.0\times10^6$	2.6×10^7	1.1×10^7	7.8×10^6	7.0×10^4	$>3.0\times10^6$	$>3.0\times10^7$
37.5°C	9.4×10^4	$>3.0\times10^4$	2.8×10^5	2.9×10^5	1.8×10^5	4.5×10^5	1.1×10^5
ANAEROBIC							
37.5°C	7.5×10^4	2.9×10^4	8.5×10^4	1.5×10^5	4.6×10^4	2.7×10^5	
COLIFORMS	2.4×10^3	3.5×10^4	1.7×10^4	3.4×10^3	4.5×10^3	5.4×10^4	1.1×10^4
ALGAE	8.4×10^6	7.2×10^6	4.5×10^6	2.1×10^6	3.3×10^6	3.3×10^6	4.8×10^6

	1960						
BACTERIA	Jan. 26	Feb. 1	Feb. 8	Feb. 15	Feb. 22	Feb. 29	Mar. 7
AEROBIC							
7°C	6.7×10^6	$>3.0\times10^7$	3.9×10^7	1.4×10^7	2.6×10^6	4.9×10^6	1.0×10^7
20°C	7.0×10^6	2.9×10^7	2.3×10^7	1.6×10^7	3.0×10^6	1.8×10^7	1.2×10^7
37.5°C	1.3×10^5	2.3×10^6	3.4×10^5	2.1×10^5	1.2×10^5	9.6×10^5	5.5×10^5
ANAEROBIC							
37.5°C	2.0×10^4	2.2×10^4	6.8×10^4	1.9×10^5	1.3×10^5	7.5×10^5	2.0×10^4
COLIFORMS	1.9×10^3	1.7×10^3	$>2.4\times10^4$	7.9×10^3	1.1×10^3	7.0×10^2	1.4×10^4
ALGAE	3.9×10^6	3.4×10^6	TNTC	3.6×10^6	5.8×10^6	3.8×10^6	

	1960	
BACTERIA	Mar. 14	Mar. 21
AEROBIC		
7°C		$>3.0\times10^7$
20°C	1.0×10^7	$>3.0\times10^7$
37.5°C	2.1×10^5	$>3.0\times10^6$
ANAEROBIC		
37.5°C	7.5×10^4	3.5×10^4
COLIFORMS	3.5×10^3	2.4×10^3
ALGAE		3.5×10^6

TABLE XXX

MICROBIAL POPULATION OF EFFLUENT AT VARIOUS LOCATIONS IN THE DRAINAGE COURSE AT LACOMBE

October 28, 1959

FINAL EFFLUENT JUST BEFORE THE CREAMERY WASTES ENTER INTO THE DRAINAGE COURSE:

AEROBIC BACTERIA			ANAEROBIC BACTERIA	COLIFORMS
7°C	20°C	37.5°C	37.5°C	37.5°C
2.2×10^{0}	1.5×10^{5}	6.4×10^{3}	7.1×10^{4}	5.4×10^{2}

JUST AFTER CREAMERY WASTES ENTER THE DRAINAGE COURSE:

9.0×10^{4}	5.0×10^{5}	3.4×10^{3}	2.2×10^{4}	1.6×10^{3}

FIRST R.A. ON NORTH-SOUTH ROAD:

6.0×10^{4}	2.0×10^{4}	1.3×10^{3}	3.1×10^{4}	$< 9.0 \times 10^{-1}$

R.A. ON EAST-WEST ROAD ALONG DRAINAGE DITCH (APPROXIMATELY 4 MILES FROM LAGOON):

5.5×10^{3}	5.0×10^{4}	4.0×10^{2}	3.1×10^{3}	$< 9.0 \times 10^{-1}$

THE TOTAL ALGAE COUNT WAS NOT DETERMINED.

C. MICROBIAL POPULATIONS IN ICE SAMPLES TAKEN FROM THE SEWAGE LAGOONS AT DAYSLAND

In February, 1959, and again in January, 1960, samples of ice were obtained asceptically from several inches below the upper surface of the ice cover at a sewage lagoon at Daysland. The microbial investigation of these samples yielded the results, shown in Table XXXI.

TABLE XXXI

MICROBIAL POPULATION OF SAMPLES TAKEN FROM LAGOON ICE COVER AT DAYSLAND

Date of Sample	Aerobic Bacteria			Anaerobic Bacteria	Coliforms	Total Algae Count
	7°C	20°C	37.5°C	37.5°C	37.5°C	
February 24, 1959	$> 3.0 \times 10^6$	2.1×10^6	8.0×10^2	6.0×10^2	$< 1.8 \times 10^3$	TNTC
January 27, 1960	5.8×10^4	5.3×10^4	1.9×10^3	2.3×10^4	1.6×10^3	1.3×10^6

D. MICROBIAL POPULATIONS OF SEWAGE LAGOONS WERE SPOT-TESTED

During the summer of 1959 and during January of 1960, a number of sewage lagoons located in Northern Alberta but widely separated geographically were spot-tested. The microbial population of these lagoons are shown in Table XXXII

COMMENT

It is evident from comparison of the results presented in Table XXXII with those in Tables I to XVIII that the microbial populations of all these widely-separated lagoons are approximately the same at the same time of year. The same result is true for the algae population and the genera of algae present.

TABLE XXXII

MICROBIAL POPULATION OF LAGOONS WHICH WERE SPOT TESTED

Source of Sample	Date	Aerobic Bacteria			Anaerobic Bacteria	Coliforms	Total Algae Count
		7°C	20°C	37.5°C	37.5°C	37.5°C	
Grande Prairie	June 15/59	5.0×10^2	2.7×10^3	5.0×10^2	3.0×10^1	$< 1.8 \times 10^1$	4.8×10^5
Sexsmith		1.5×10^5	3.6×10^5	4.2×10^5	1.3×10^1	3.5×10^3	1.3×10^5
Rycroft Lagoon		8.8×10^5	4.8×10^3	1.1×10^3	8.0×10^0	1.3×10^2	5.2×10^6
Rycroft Pit		6.7×10^5	2.4×10^6	1.5×10^6	3.5×10^1	9.2×10^3	6.7×10^6
Spirit River Lagoon		6.8×10^4	2.3×10^5	7.6×10^4	1.0×10^0	$< 1.8 \times 10^1$	3.0×10^5
Sludge Pit		5.0×10^5	1.8×10^6	5.8×10^5	7.7×10^2	$> 2.4 \times 10^4$	1.4×10^6
Fairview 1	June 16/59	2.5×10^5	1.9×10^5	2.4×10^5	4.0×10^2	9.2×10^2	9.0×10^5
Fairview 3		2.0×10^3	2.0×10^2	4.0×10^2	2.0×10^1	$< 1.0 \times 10^1$	5.0×10^4
Berwyn		$> 3.0 \times 10^4$	2.0×10^4	2.3×10^4	3.0×10^1	3.3×10^2	1.8×10^5
Grimshaw		9.2×10^4	1.2×10^5	5.5×10^4	8.0×10^1	1.1×10^2	3.3×10^5
Donnelly	June 17/59	7.0×10^3	5.0×10^4	4.7×10^3	3.9×10^3	3.5×10^1	None seen
Falher		4.5×10^4	9.4×10^4	1.6×10^5	1.2×10^4	2.3×10^0	7.0×10^4
Girouxville		5.0×10^2	1.0×10^2	7.0×10^2	3.0×10^2	7.8×10^{-1}	None seen
Campbell Park Lagoon	June 29/59	2.0×10^4	5.1×10^4	3.9×10^4	4.8×10^4	3.5×10^0	$< 5.0 \times 10^4$
Slough		8.9×10^4	1.1×10^5	4.1×10^4	7.5×10^4	7.9×10^1	None seen
Riley Sludge Pit	Jan. 6/60	$> 3.0 \times 10^5$	1.1×10^6	2.1×10^5	3.0×10^4	2.4×10^4	2.3×10^6
Myrnam Sludge Pit	Jan. 20/60	1.2×10^6	9.1×10^5	3.3×10^5	2.6×10^5	9.2×10^5	5.5×10^6
Lagoon		5.1×10^5	7.7×10^5	1.1×10^5	3.0×10^4	3.5×10^4	6.2×10^6
Two Hills 1		1.6×10^6	2.3×10^6	4.3×10^5	1.1×10^5	1.3×10^4	2.7×10^6
Two Hills 2		1.4×10^6	2.7×10^6	4.4×10^5	1.1×10^5	1.7×10^5	3.6×10^6

NOTE:

The appendices referred to in this report are those included in the thesis "An Investigation of the Microbial Flora of Sewage Stabilization Ponds" by A. A. Garden, M. Sc. University of Alberta, September, 1960.

NOTE:

The abbendices referred to in this report are those included in the thesis "An Investigation of the Microbial Flora of Sewage Stabilization Ponds" by A. A. Ortega, M. Sc. University of Alberta, September, 1960.